AN

INVESTIGATION

OF THE

CURRENTS

OF

THE ATLANTIC OCEAN,

AND OF THOSE

WHICH PREVAIL BETWEEN THE

INDIAN OCEAN AND THE ATLANTIC.

BY THE LATE

MAJOR JAMES RENNELL, F.R.S.

OF LONDON AND EDINBURGH, MEMBER OF THE ROYAL INSTITUTE OF FRANCE, OF THE IMPERIAL ACADEMY AT ST. PETERSBURG, AND OF THE ROYAL SOCIETY OF GOTTINGEN; AND FORMERLY SURVEYOR-GENERAL OF BENGAL.

THY way is in the sea, and THY path in the great waters, and THY footsteps are not known.

PSALM lxxvii. 19.

LONDON:

PUBLISHED, FOR LADY RODD,

BY J. G. & F. RIVINGTON,

ST. PAUL'S CHURCH YARD, AND WATERLOO PLACE, PALL MALL.

1832.

LONDON:
GILBERT AND RIVINGTON, PRINTERS,
ST. JOHN'S SQUARE.

TO THE KING.

Sire,

Your Majesty's gracious commands, respecting the dedication of this Work, enable me to fulfil a most pleasing duty, by recording the deep sentiments of gratitude entertained by my late revered father, for the honour your Majesty, when Lord High Admiral, was pleased to confer upon him, by offering to take this Work under your protection; the declining health of the Author, and a reluctance, which he manifested on all occasions, to give any thing to the public while there was a possibility of making it more complete, prevented this desirable event taking place, and the proud task now devolves

His Majesty has likewise commanded me to state that, when Lord High Admiral, his attention was first drawn to the great scope and importance of the undertaking, through the discerning zeal of EARL SPENCER; and I should scarcely fulfil my Father's intentions, were I to neglect this occasion of expressing his gratitude for the lively interest that his Lordship took in all his literary pursuits.

Though it would be impossible to do justice to the generous eagerness with which materials were proffered to the Author, I may not omit to thank Mr. Barrow for his ready communication of any thing that could be of use to the Work, as well as for his kind endeavours to bring it under the notice of the Admiralty.

To Mr. John Purdy I feel under great obligation; my Father's high opinion of his talents induced me to select him to be the Editor, and the judicious manner in which he has executed his trust has more than justified my confidence.

JANE RODD.

WIMPOLE STREET,
Aug. 6th, 1832.

THE CHARTS OF THE CURRENTS,

Which this Work is designed to illustrate, are as follow:

CHART I.—The Eastern Division of the Atlantic Ocean, from the latitude of 43° south, to that of 56° north, and from longitude 20° east to 41° west.

CHART II.—The Western Division of the Atlantic Ocean, from the latitude of 43° south, to that of 56° north, and from longitude 35° west, to 97° west.

CHART III.—Southern Africa, with the Lagullas Current, and the Counter Current from the Atlantic to the Indian Ocean.

CHART IV.—The Currents between the Indian and South-Atlantic Oceans; with that, in the southerly region, which favours the passage of Ships towards Australia and Van Dieman's Land.

CHART V.—The Florida or Gulf-Stream, on an enlarged scale.

PLATES IN THE VOLUME.

CHART VI.—A General or Index Chart, displaying the whole at one view. (*Facing the Title.*)

CHART VII.—Rennell's Current, which sets, at times, athwart the English Channel. Page 300.

THE VOLUME IS ARRANGED AS FOLLOWS:

CHAPTER I.

CHAPTER II.

ENLARGED DESCRIPTIONS and DETAILS of the several CURRENTS.

APPENDIX.

INVESTIGATION

OF

CERTAIN STREAMS OF CURRENT

IN THE

ATLANTIC OCEAN.

CHAPTER I.

GENERAL OBSERVATIONS ON, AND VIEW OF, THE SYSTEM OF CURRENTS.

SECTION I.

GENERAL OBSERVATIONS ON WINDS AND CURRENTS.

[INDEX CHART.]

ALTHOUGH the CURRENTS of the OCEAN form a most important part of HYDROGRAPHY, yet it is only since the introduction of chronometers, and of celestial observations for the longitude at sea, (that is, not much more than forty years ago, [1]) that a competent idea of their direction and force, in any kind of detail, *could* be obtained. For, although the differences in northing and southing, between the dead-reckonings and observations, might be

[1] This was written in the year 1820.—ED.

pointed out by the observations of latitude, yet the error of longitude, or of easting and westing, would, of course, escape detection altogether: and it happens that, in the ATLANTIC OCEAN, which forms the scope of the present inquiry, the streams of current, which most materially affect navigation, both in respect of extent and velocity, run more easterly and westerly than otherwise. To the invention of chronometers then, and to the improved methods of finding the longitude at sea by celestial observations, to check their *rates* of going, navigators are indebted, as well for expediting their passages as for greater safety in the mean time: and the invention, as it respects *currents*, is surely in the next degree of importance to that of showing the ship's place, which may be so much affected by them, during the long intervals that occasionally happen between the celestial observations, and for which a delineation of such streams of current as are prevalent, would prepare the navigator.

The progress in the knowledge of this subject has, accordingly, been very great, since the date of the above invention; and, to every person the least informed concerning nautical science and practice, the use of such knowledge must be obvious. For, in whatsoever line of direction a portion of the ocean may move, it must rarely happen that it is neutral in respect of a ship's course; but that, on the contrary, it will either favor or impede it. A knowledge of the truth, therefore, will enable the navigator so to arrange

his course as to render the current the most advantageous in the one case and the least disadvantageous in the other: or, in certain cases, to avoid delay or danger. For instance, a just idea of the nature of the *Equatorial Current* would prevent a commander from crossing the equator too far to the westward in the southern passage; particularly at the season when the S.E. trade-wind is very far southerly; and when, also, the current runs so strongly to the westward, in the neighbourhood of Cape St. Roque, as to hazard his being driven to leeward of it. Again, a winter passage round the Cape of Good Hope to the westward may depend on keeping in the stream of the *Lagullas Current*: and, by a thorough knowledge of the same current he may be enabled to prevent its setting him on the *Telemaque Rocks*[1]. So that it was very truly said, forty-two years ago, before chronometers came into use, that hitherto "the difficulty of ascertaining currents is well known to be one of the greatest defects in the present state of navigation[2]."

[1] Major Rennell retained to the last an opinion that the *Telemaque Rock* or Rocks existed; although not in the situation generally assigned. They were sought for, but unsuccessfully, by Captain Hanmer, in H. M. S. *Heron*, 1821, as shown on Commodore Owen's chart of Southern Africa. A communication made to Major Rennell on this subject, will be found in § 5, of the *Appendix* hereafter.—Ed.

[2] Sir Charles Blagden on the Gulf Stream, 1778.

The effects of these currents, in one particular tract, will be best understood by the following statements.

Between the *Cape Verde Islands* and the *Cape of Good Hope*,

The author having employed a large portion of his leisure in collecting materials for illustrating and explaining the subject of the currents of the ocean generally, and more particularly for those in the Atlantic and Indian Oceans; and in forming a system conformable to these observations; flatters himself that the work at large will meet the approbation of those who are competent judges of it. His personal knowledge (and perhaps he may be allowed to add some degree of former professional knowledge) of such subjects, has furnished him with the means of appreciating the value of a great proportion of the materials that

in June and July, a ship was carried ten degrees of longitude to the west, equal to 570 geographic miles; and yet had been subject to an *easterly* current after leaving the south-east trade-wind.

Another was set, between the *Canaries* and the *coast of Brasil*, in June, 220 miles.

Another, in the *Equatorial Current*, in June and July, was set, in five days, consecutively, 297 miles; and, between 3° N, and $4\frac{1}{2}$° S, the same ship was set, before she could extricate herself from the Equatorial stream, (and yet had entered the S.E. trade,) 390 miles.

Another, between *St. Helena* and *thirty degrees north*, in December, 285 miles.

Another, from *St. Helena* to *four degrees north*, fifteen days in June, 383 miles.

Note.—Before the date of observations all that could be known was the balance of the easting and westing at the landfall, without knowing *when* they were subject to one current or the other. It is proper to observe that, in the above statements, the northing and southing are not taken into the account; by which the currents appear very much *weaker* than they really were.

engaged his notice, as well as of adding to the whole the result of inquiries and observations made on the spot.

The formation of a great number of facts into a system, may, it is presumed, prove of use in impressing those facts on the mind more strongly than if they were left to operate independently of each other. For oftentimes a fact makes less impression, when standing naked and alone, than when it makes a part of a system, which operates like a band to keep the parts together in their proper places, when they may happen to explain and illustrate each other.

The present work is confined to the PRINCIPAL STREAMS of CURRENT in the NORTH and SOUTH ATLANTIC OCEANS; and those which pass between the INDIAN and SOUTH ATLANTIC OCEANS, round the Cape of Good Hope: together with the regions of the TRADE-WINDS in the two Atlantics; showing the changes that take place in the different parallels and seasons; a most important point of knowledge to such as are strangers to that navigation, and may expect to find the trade-winds more regular.

An attempt to describe the currents of the *whole circumambient ocean* would have been too great an undertaking for any individual advanced in life, even if proper materials could have been found: and, therefore, it was supposed that, since no greater scope could be taken than that which the Atlantic presented, it was, of all others, taken singly, of the most immediate use to navigation. Besides,

there are not, perhaps, in the other oceans such a variety of currents; or, at least, so many which affect navigation so much and so critically.

It appears that scarcely any portion of the surface of the ocean remains still: and, doubtless, this is amongst the wise dispensations of THE CREATOR, to preserve its purity; as the *tides* do not occasion an absolute removal of the water from one place to another, except very near the coasts; and even that motion very much circumscribed.

The WINDS (with very few exceptions) are to be regarded as the prime movers of the currents of the ocean: and, of this agency, the TRADE-WINDS and MONSOONS have, by far, the greatest share; not only in operating on the *larger half* of the whole extent of the circumambient ocean, but as possessing greater power, by their constancy and elevation, to generate and to perpetuate currents: and, although the monsoons change half-yearly, yet the interval during which they continue to blow, in each direction, is long enough to produce effects nearly similar to the operation of the constant trade-winds. And next to these, in degrees, are the *most prevalent* winds; such as the westerly winds beyond, or to the north and south, of the region of trade-winds.

The wind then, operating incessantly on the surface of the ocean, causes, in the first instance, a gentle, but general, motion of the fluid to *leeward;* (as is proved by ships being always found to leeward of their reckonings, in the trade-winds;) and the water so put in motion, forms, by accu-

mulation, streams of current, the process of forming which will be detailed in the sequel.

It therefore becomes necessary, since the wind is so powerful an agent, not only in *generating*, but in *keeping up*, the currents, to give the reader, at the outset, some general ideas concerning the trade-winds, monsoons, &c., and the changes, to which they are subject, in the North and South Atlantics; in order that he may be enabled the better to understand the nature of those changes; whether operating separately, or combined with the effects produced by the position and distribution of the land.

Regarding the bulk of my readers as being sufficiently informed concerning the general subject of the trade-winds, I shall not offer any thing like elementary matter; more especially as the detail of the observations is before them: but confine myself to such particulars as may serve to explain the manner in which the currents of the sea are produced by them[1].

I shall begin with a slight *outline* of the *regular* trade-winds, and conclude with that of the monsoons; since such winds do actually exist, in degrees, in both Atlantics; as well as in the Indian Seas.

TRADE-WINDS.—Although, with great propriety, the *trade-winds* are denominated N.E. and S.E., as blowing from the quarters so called (in the absence

[1] The direction of the winds in the charts is the *true* direction, cleared of *magnetic* variation.

of monsoons), yet they both vary at different seasons, and in different parallels, through most of the points of the compass, of their respective quarters: for they have, at all seasons, a direct tendency to blow *towards* the place of the sun; or *less wide* of it. So that the N.E. trade is more northerly when the sun is in the southern signs; and the S.E. more southerly in the opposite season.

Both trades also, when free from the influence of *monsoon*, blow more northerly and southerly, in the regions adjoining to the old continents, than towards the middle of the ocean: for, as we recede from the coast, the wind gradually becomes more and more easterly; and finally almost an easterly wind.

Their limits, too, in point of parallel, vary with the position of the sun in the zodiac; the whole breadth of the trade being, as it were, drawn towards it.

A pretty general error prevails, amongst persons not practically informed, concerning the extent of the trades. The parallels of 30°, north and south, are taken to be the exterior limits of these tracts in all the three oceans; but 28½° may be more correctly taken, as a mean in the Atlantics. Sometimes, the variable winds beyond them may be eastwardly; and then they may be reckoned, by inexperienced persons, as a part of the trade itself: for occasionally, ships find, of course, a N.E. wind at Madeira, although more than three degrees beyond the trade; and a S.E. wind at leaving the Cape of Good Hope, in more than 34°.

The two trade-winds in the Atlantic have different characters. The N.E. one is sometimes stormy, particularly in its northern part, and far from the eastern continent. It is there, also, at times, extremely variable. A very experienced and intelligent commander, in the East-India service, reports that, a few years since [1], the N.E. trade was reduced, in breadth, to nine degrees only; and that in more than one zone: and, moreover that it was so arranged that the N.E. wind extended to several degrees across the equator, where it ceased.

The interruptions in both of the regular trade-winds by the monsoons will be considered hereafter.

The S.E. trade-wind, it has been observed, is more regular than the other, and is much more serene. Its northern limit comes up, in the summer season of the northern hemisphere, very far to the northward of the equator; so that its mean annual limit is in about $2\frac{1}{2}^{0}$ N.; which is probably occasioned by the excessive heating of the land of Africa, near the equator. The N.E. trade seldom proceeds so far south as to reach the equator.

It has been remarked that both trade-winds, in the regions towards the old continent, blow more directly towards the equator than in the ocean at large. The S.E. trade, in particular, continues very far southwardly; so that, within a line drawn

[1] The month is not given, but it may be presumed that it was in the latter part of winter in the northern hemisphere.—Ed.

from 2° N., longitude 15° W., towards Sierra Leon, the wind is seldom to the eastward of S.E.; but becomes more and more eastwardly, as it proceeds westward; in the same manner as in the North Atlantic.

A *partial* monsoon,[1] in both Atlantics, has been spoken of above, and will be found to interrupt, very greatly, the regularity of both.

It is proper to observe that, besides the mere effect of the *position* of the land, in intercepting or diverting the course of the regular trade-winds, the great mass of land itself is sometimes so unequally distributed, in the equatorial parts of the globe, that *all the land* lies on one side of the equator, and all the sea on the opposite side: as, for example, the coast of *Guinea* in Africa; *Brasil* and *Guyana* in South America. This state of things has the effect of producing, to a very great distance from the land, PERIODICAL WINDS, as the sun visits and heats the northern and southern hemispheres alternately; in effect, converting the trade-wind into a *partial monsoon*, during the season when the sun occupies that side of the equator in which the land predominates; substituting a S.W. MONSOON for the regular N.E. TRADE, through ten or twelve degrees of latitude, along the western coast of North-Africa;

[1] By a *partial monsoon* is meant a stream of air which does not extend all the way across the sea, as on the coast of Brasil, Northern Africa, and Mexico; and not as in the Indian Ocean, between Madagascar and Java, &c.

and in the ocean it is so nearly half-way across, towards America. And, in like manner, changing the S.E. trade into a N.E. MONSOON, along the coast of Brasil. These, so far as they go, are real MONSOONS, although not so denominated as in the Indian Seas, from which the term is borrowed [1]. In Asia, the great body of the land, through a course of more than seventy degrees of longitude, (that is, India at large) is almost wholly confined to the northern hemisphere; producing what may be considered as an *annual land and sea breeze;* that is, the alternate *heating and cooling* of the land; only, that the process, in the one case, is gone through in the course of a natural day, but that the other requires the course of a year.

It may be calculated that, of the equatorial parts of the coasts of the globe, three-fifths are subject to the operation of monsoons; either wholly or partially. Thus, in the Indian Ocean, from Madagascar to New Guinea; in the Pacific, the coast of Mexico; and in the Atlantics, as we have seen, in different portions; comprehending, altogether, a large extent of coast [2].

[1] The term MONSOON (or rather MOUSOON) amongst the native mariners in the Indian Ocean, is said to mean nothing more than SEASON; that is, the vicissitudes, or changes, of seasons.

The author has been told, that the Liverpool traders do, or did, call the season of the S.W. winds on the coast of Guinea, "*the Line westerly monsoon.*"

[2] So little general knowledge on this subject did our mariners possess, at the date of Lord Anson's expedition (1740), that his Lordship appears to have been surprised not to have found the

An opportunity occurs of determining, generally, to what distance off shore the influence of the

regular N.E. trade-wind at 70 or 80 leagues to the westward of *Acapulco*, in the month of May. Nay, his editor, Colonel Robins, so well informed on other subjects, expresses his surprise also; and never seems to have thought of a monsoon, although here were all the characters of one before him; and the monsoons in the Indian Seas had been familiar to our navigators more than a century and a half, and Dr. Halley had previously written on the subject of winds.

Nor does it seem to have been known to the persons concerned in the expedition, that the galeons from Acapulco to Manilla were forbidden to sail from thence after the month of March, on occasion of the season of S.W. winds.

By the chart of Lord Anson's track in the relation of the voyage through the Pacific, it seems that he found the N.E. trade-wind in latitude 7°, and at about 700 miles from the coast of Mexico; which does not differ greatly from the result obtained from Mr. Fitzmaurice's report, on the eastern coast of Brasil.

* * * * *

Having mentioned Admiral Lord Anson, I ought not to omit a circumstance, exculpatory of that highly distinguished officer, in a case where he was wrongfully blamed. And this I do, because it is probable that the truth is known to very few persons.

After the elegant and interesting narrative of the voyage had been considered, it was remarked by some professional men, that it contained little or no nautical information, that could be useful to future navigators.

But, in fact, a *second* volume, containing the nautical parts, was in preparation, but had not kept pace with the other (which the reader may perhaps easily account for, as well as for the exclusion of the supposed *dull* matter, from the narrative). Mean time Colonel Robins, the author, was appointed Engineer General to the East India Company, and sailed for India, taking the MS. with him, under the idea that it required correction, or examination; but very contrary to Lord Anson's wishes. The

monsoon which displaces the S.E. trade on the coast of Brasil extends. Mr. Fitzmaurice (who with so much trouble and difficulty brought home the two ships of Captain Tuckey from the Congo expedition) touched in his way home at *St. Salvador, or Bahia*, in lat. 13° 1′ S., long. 38° 32′ W., in the month of December, a season which may be reckoned the height of the N.E. monsoon of the coast of Brasil. The N.E. wind compelled him to stand to the S.E., until he reached longitude 24° in the parallel of 21° 50′, which was no less than 940 miles from St. Salvador, and 860 from the nearest shore of Brasil; and here the wind first enabled him to lay the ships' heads to the northward, in his way home. This result is very satisfactory; as being founded on a *series* of *examples*, and not on *casual* ones; of which we had no other kind before.

It remains to give a word or two concerning the *winds beyond the trades;* and which, although not operating *constantly*, yet return so frequently to their accustomed quarter, (the western,) that they are reckoned to blow nine days from the western side of the meridian, to about five and a half from the opposite side; but still produce so slow a current, in the North-Atlantic, clear of the Gulf stream, as only to manifest itself generally, on the whole course of a voyage, as from America to Europe. This subject will be discussed at large

Colonel lived but a short time in his new situation; and after his death not a vestige of the MS. could be found.

hereafter, and will appear curious, from the sameness of the results; which arise from experiments, made with floating bodies, either intentionally or accidentally employed.

Exceptions have been alluded to, in respect of the origin of currents, from the operation of the wind on the surface of the water. Some of these may be produced by the inequality of the quantities of evaporation in different parts or members of the same ocean, occasioned by the different temperatures of their surfaces; as by the Mediterranean Sea, &c. Another sea may receive more water than it can evaporate, and sends forth the surplus in the form of a current, like the Euxine. Or, by the accumulation of ice and snow during a long winter, an additional mass of water is sent forth from the Polar Seas, at the end of spring and during summer.

The North-Atlantic Ocean supplies the *waste* occasioned by the increased degree of evaporation of the Mediterranean Sea, that sea being proved to be, in summer, 5 or 6 degrees warmer than the corresponding parallels in the adjoining Atlantic: whence one may naturally refer the current of the Strait of Gibraltar to the increased evaporation of the Mediterranean; for it will appear by the Chart of Currents, [*Chart* I.] that the whole of that part of the Atlantic, which washes the shores of Spain, Portugal, and Barbary, from Cape Finisterre to the parallel of the Canary Islands, and thence round in a curve, touching the 20th degree of longitude; is in motion towards the

Strait of Gibraltar. And yet the evaporation of the Mediterranean is barely compensated by the supply; for its eastern basin still remains much lower than the Red Sea, according to the French observations in Egypt.

No one can well doubt that the removal of such a vast mass of water, from the Atlantic into the Mediterranean, must produce a constant depression of level in that part of it.

This current, by carrying ships out of their course, towards the shore of the African desert, is the cause of numerous shipwrecks between Marocco and Cape Verde, when the crews and passengers are condemned to certain and cruel slavery. It is the more lamentable, in that the cause is well known, and has been so clearly pointed out, and could be guarded against, by the slightest attention. In the detail of the *North-African Current*, I have inserted a repetition of the caution, together with the mode proposed to impress it daily on the memory.

Again, the vast expanse of warm water, spread over the central part of the same Atlantic, by the agency of the *Gulf-Stream of Florida*, comprehending in itself a surface probably equal to the whole area of the Mediterranean Sea, and 8 or 10 degrees warmer than the ocean in which it is deposited; must, in like manner with the other, occasion a depression of surface and a like result; which one would conclude to be a current of some degree or other.

The other principal exceptions are, the North-Polar Sea, Baltic, and Hudson's Bay.

Of the second and third kinds of exceptions,—namely those currents produced by a redundancy of water in lesser seas communicating with larger ones, either by receiving more than they can evaporate; or, by the accumulation of snow and ice in winter; or both. There are,—first, the *Euxine* or *Black Sea;* second, the *Baltic;* third, *Hudson's Bay;* and fourth, the *North-Polar* and *Siberian Seas.* The first is clearly owing to the superabundance of river water which it receives, and the smallness of the discharge at the Bosphorus, in proportion to the other, may serve to show how great the evaporation in such cases must be. The Baltic and Hudson's Bay may be regarded as mixed cases; although in very different proportions. The Northern Polar Sea receives a vast supply of river-water from the Asiatic and American continents; in effect, the drainage of all the tract northward of the 50th degree of latitude: so that a current from it must be expected throughout the year; but very much stronger during the melting of the ice and snow that has accumulated during winter.

But the great width of the outlet, between Greenland and Lapland, must necessarily reduce the force of the current; and probably *streams* will be found only to the west of Spitzbergen, and along the coast of Lapland. The information is very clear respecting the former, from the parallel of

Spitzbergen to that of Cape Farewell, by the experience of Captain Scoresby, by the miserable fate of the Dutch fleet in 1777, and by the observations of Captain Parry, in 1818. The other is known to range generally along the north coast of Asia, and is traced through Waygat's Strait towards Lapland[1]: and it may be supposed that the westerly current observed by Captain Parry, in his way westward from Shetland, in May, 1818, is a continuation of that stream. But this stream appears to be only periodical; that is, during the spring and the summer; for, on his return, at the *end* of *October*, it ran in an opposite direction. But the Greenland current was *constant;* and appears to be the same stream which is known to

[1] Captain Burney, in his interesting History of North-eastern Voyages of Discovery, mentions a circumstance which is very much in proof of this general current. A Russian ship was found cast away on the south coast of Spitzbergen, in 1739, not damaged, and having provisions on board. It appears highly probable that this was the ship of Lieut. Laptieu, who was on a voyage of discovery, in 1739, and whose ship was *frozen in* and abandoned, at about 40 miles from the mouth of the Indigirka river.

This article is the more important, as it serves to show the *general course* of the outfall of *that side* of the Arctic Sea: and consequently, the reason why its ice is borne clear of ours and of the neighbouring shores. (There is, however, a *report*, from good authority, of a *stray* ice island having been seen, in our times, between the *north of Ireland* and *Shetland.*)

The vast quantities of *drift wood* found on *Iceland, Spitzbergen,* and *Jan Mayen's* Island; some of it with marks of tools on it, is probably brought by the same currents, from the mouths of the Siberian rivers. It is difficult to account for its coming any other way.

bring down the ice along the eastern side of the great bank of Newfoundland ; whence it is said to continue southward, and to join the Gulf-stream, between 43° and 44° of latitude, and 45° to 50° of west longitude. Ice has been seen as far south as latitude $40\frac{3}{4}$°, and as far east as longitude 46° W.

Of the circumstances respecting the current through Bhering's Strait, into the Polar Sea, we have no certain knowledge, but during the height of summer. The report of *Kobelef*, quoted by Captain Burney, says, that "after the month of August, the current changes and runs to the *south;* (that is, from the Polar Sea, into the Pacific ;) bringing with it the floating ice." Such a change, and at that particular season, appears to be a very extraordinary fact; and to rest on a single authority. The truth must certainly be known in Russia.

Concerning the *Antarctic* region, we know but little; whether it be land or sea; but Captain Cook always found currents running from thence to the northward. Those will naturally be referred to the melting of the ice and snow, in summer : it was only during that season, that he had any opportunity of gaining information. But if there be no great portion of land, and the ice be all floating, the author is at a loss to understand how snow, falling on it, should cause the level of the sea to be different from what it would have been had water fallen, instead of snow: because the weight of the snow must, by pressing down the ice, occasion the displacing of an equal weight

of water; and therefore, although there may be more ice and snow accumulated, yet the level of the sea would continue the same, on its melting. It can be only the melted ice or snow on the *land*, or on ice *aground*, that can raise the level, on melting.

Having given this general outline of the origin and nature of currents, it may be useful in this place to state, in abstract, the principal streams that prevail in the Atlantic, and which are meant to be treated of, either generally or particularly, as occasion will arise, to allude to many of them, in the course of the present discussion; and which allusions might not otherwise be easily understood.

SECTION II.

A GENERAL VIEW OF THE SYSTEM OF CURRENTS IN THE ATLANTIC. [INDEX CHART.]

Having given the above ideas respecting the origin and nature of Oceanic Currents, I now proceed to enter into a General Description of the courses and circumstances of each of those streams which are the most extended in their courses, or most powerful in their effect on Navigation. I shall first enumerate them, and describe, very shortly, their positions and connexions.

It cannot be otherwise than that, as these streams cross both the Atlantics, in certain parts, and wash

their coasts generally throughout the whole, besides the connexion arising from the intermediate *drift* currents between the greater streams; there must, necessarily, be a general communication between them; and this leads me to observe that, on the whole, the waters have a greater tendency towards the middle of the North-Atlantic than otherwise. Whether this be really occasioned by its level being reduced by the supplies constantly afforded to the Mediterranean, and to the increased evaporation from its own body, (as has been before supposed,) or whether it be only that the position of the shores of the South-Atlantic are better adapted to aid the operation of the south-east trade-wind, in impelling the water to the northward and westward, where it finally meets with no counterbalance from the effect of the N.E. trade; may be a question.

But, be it as it may, the *effect* is such as seems to countenance such an opinion as that of a *lower* level of the North-Atlantic: at least, it is unquestionable that there is *one and the same line of current from the Cape of Good-Hope, north-westward, towards and through the West-Indies and Strait of Florida;* and occasionally home to the shores of Europe. I shall, therefore, begin the enumeration at the Cape of Good-Hope, as the point the *highest up in the stream.*

1.—The SOUTH-ATLANTIC CURRENT. [Chart I.]

There is a real STREAM off the Cape of Good-Hope, which is a portion of the well known *La-*

gullas Current, a current which, as described hereafter, makes its way into the South-Atlantic, round the Cape and the Bank of Lagullas, and thence proceeds along the western coast of South-Africa to the Equator. This is, in effect, the first o the *Stream* Currents [1] meant to be noticed in this list, (the *first link* of the stupendous *chain* before us;) and which, by the aid of adjunct waters, collected in its progress, becomes the *prime mover* in the great machine.

By the time that it arrives on the coast of Congo and at the river Zahir, it is become a powerful and very extensive stream, as shown by the chart: and now the coast of Africa, bending rapidly to the N.W. and West, to form the Bay or Bight of Benin, &c., turns the current in question to the

[1] I distinguish two kinds of currents. The one *drift* or *drift current*, is the mere effect of a *constant* or *very prevalent* wind on the surface-water; impelling it to leeward until it meets with some obstacle which stops it, and occasions an accumulation, and consequent *stream* of current. It matters not whether the obstacle be *land*, *banks*, or a *stream of current* already formed.

The other, of course, is the *stream* current, formed of the accumulated waters of the *drift* current. This may be of any *bulk*, or *depth*, or *velocity*; but the other is shallow, and at a mean, perhaps, of no more than half a mile per hour, when the wind is constant and a good breeze.

With respect to the drift being opposed by a stream already formed, (which often happens,) it may either fall into it, and, consequently, augment it; or it may form a stream of itself, and run in a contrary direction to the other. That is, if the *drift* points obliquely *towards* the course of the *stream*, it will fall into it: but if obliquely *from* it, it will form a stream of itself, in an opposite direction to the other, and very commonly *brush* it. *(See farther "On the Causes of the Currents" hereafter.)*

westward, along the Equator; whilst the *Guinea current*, coming from the North-Atlantic, meeting it, passes *within*, and nearly brushes it, in its way to the Bight of Benin; where it terminates, partly by dispersion within its ample space; partly by its being *barred up* by the lands to the eastward; and partly by its meeting the oceanic waters on the south; and thus the *South-Atlantic current* is suddenly converted into an *incipient Equatorial stream*.

2.—The EQUATORIAL CURRENT. [Chart I.]

This stream continues its course along both sides of the Equator, having crossed it very obliquely at its commencement. It receives constant supplies from the drift current of the South-Atlantic, so that by the time it has reached the middle point between the two continents, it has acquired, during the season of the northern summer, a vast breadth; and, in some places, a rate of three miles per hour. It is, doubtless, the most powerful and the longest extended stream of all those in the Atlantics; and, by its nature and position, interferes the most of any with navigation; forming a wide and complete bar across the narrow part of the Atlantic, between the coasts of Guinea and Brasil; and causes the greater annoyance, inasmuch that, at the time of its greatest breadth and strength, the S.E. trade-wind, by its being very much southwardly, prevents a ship from escaping readily from a current which is carrying her rapidly out of her course.

The length of course of this remarkable stream,

reckoning from the Bight of Biafra to the Antillas or West-Indian Isles, is, roundly, about 4000 geographic or nautic miles; but, even reckoned only to the N.E. promontory of South-America, (*Cape St. Roque,*) it is about 2500.

At the aforesaid middle point between the two continents, and precisely at the equator, the stream (now considerably widened) sends off a very large branch to the *northwest*, and into the midst of the North-Atlantic; whilst the main stream turns to the W.S.W.; pointing to the promontory of Cape St. *Roque*: and, when it approaches that cape, it subdivides; the largest part passing by the north of the Cape, towards the West-Indies; the other southward, along the eastern coast of Brasil; and is felt, in degrees, all the way to Cape Horn.

The *main* stream, after passing Cape St. Roque, although divested of two such great masses of water, is still a great and powerful stream, now receiving supplies from the N.E. trade on the right, as before from the S.E. trade on the left, and widening out to an indefinite extent, whilst its rate of motion is from three miles to one mile an hour.

This is the *second* and longest link of the chain, when the Gulf-stream (hereafter described) terminates at the *Azores*.

3.—THE CARIBBEAN OR COLOMBIAN SEA. [CHART II.]

One is doubtful whether to regard this sea, wholly as a *stream of current*, or as a *sea in motion*: for such is its description, rather than a stream of current. The southern part of it is, in effect, a

continuation of the Equatorial stream, which enters the Caribbean, through the passages between the Islands in the chain of the Caribbees (or Antillas); and it may be observed that the streams through the channels between Dominica and the continent, to the south, are very much stronger than those on the opposite side. But the general motion of this sea is vastly more gentle than that of the Equatorial stream. This may be called the THIRD *link of the chain of currents;* and may be reckoned to be more than 1600 miles in extent.

4.—THE MEXICAN SEA OR GULF. [CHART II.]

This may be regarded as the *reservoir* of the GULF-STREAM; since it keeps up, at all times, a *head* of *water* for the supply of the stream. It is commonly supposed that it must have a great degree of elevation above the Atlantic Ocean; which seems requisite, in order to produce such a phenomenon as it produces: but the cause of this elevation has been very differently accounted for. In the discussion of this subject, at large, I have endeavoured to clear it from some of its difficulties.

I shall only mention, in this place, that it appears probable that the N.E. trade-wind forces a great quantity of water from the *Atlantic* into the Sea of *Mexico*, through the *Caribbean* Sea; and which it could not readily escape from through the narrow Strait of Florida.

The water passes with a gentle current, from the *Caribbean* into the *Mexican* Sea, through the Channel of *Yucatan*; and may be considered as

making a tour of the gulf, or sea, by the left (or S.W.,) passing by *Vera Cruz* and the mouth of the Missisipi River; and, finally, completing it opposite to the Channel of *Yucatan* and the west end of *Cuba*, which separates that channel from the outlet of the Strait of Florida. [*See Chart* V.] Here the current of the Mexican Sea becomes greatly augmented, by the effect of the *indraught* of the Strait; and is much too wide to be admitted, in its whole body, into the Strait; whence it happens that, a part of it passes wide to the S.W., and falls on the west end of Cuba; from whence it is deflected round Cape *Antonio*, and into the Caribbean Sea; thereby placing persons, unused to the navigation, sometimes in danger, from the Colorados shoals; which this S.W. flank of the current has a tendency to produce. The safest course, therefore, round Cape Antonio, from the southward, is allowed to be *northwestward;* until the ship is arrived in the *fairway* of the *Florida* current or stream.

The water of this sea attains an unusual degree of warmth; it being seven, or more, degrees of warmth higher than that of the Atlantic, in the same parallel and season. This seems to be much the case with other *close* seas, the Mediterranean, in particular, is 5° or 6° warmer [1].

[1] All *close* seas have the highest temperature, as the Mexican Sea and Mediterranean. The former has the highest that the author has yet known, by several degrees.—This is the reason why the temperature of the Gulf-stream forms *so great* a contrast to that of the Atlantic waters far to the northward.

The Channel of *Yucatan*, between Cape Catoche and Cape Antonio, terminates the chain of currents, *westward*.

5.—The FLORIDA or GULF-STREAM.
[Charts II. and V.]

The Florida or Gulf-stream is still a continuation of the same stream, or *series* of *streams*, with the one we set out with: (viz.) the *South-Atlantic*.

The Caribbean and Mexican waters having carried us to the extreme point of distance of our subject, westward, the Gulf-Stream now brings us back, a considerable way, on the circle.

This article is by far the most curious, as well as the most intricate, of any that are likely to be presented to the reader: and the investigation of it may possibly serve to explain some difficulties, which may have occurred to him, in his former method of considering the subject. For, it appears to the author, that the changes observable in its path and volume can no otherwise be understood, or accounted for, than by considering it in the nature of an *immense river*, descending from a higher level into a *plain*: that river at all times filling its bed, and being subject to frequent and very great *floods*.

The Gulf-Stream, then, having commenced at the head of the Florida Strait, pursues its way, first to the north and then to the N.E. along, and not far from, the coast of the United States, to *Cape Hatteras*, where the coast turns much more to the *left*, but the stream gradually more and more to the

right or eastward; and finally points between the E. by N. and E.N.E., through the Atlantic, (no more approaching any part of America,) until its northern edge touches the parallel of 44½°, in about longitude 43° west; or midway between *New York* and *Cape Finisterre*. Here it begins to turn from north of east, to south of east; and gradually round to south, and W. of S., by the time that it arrives in the parallel of the *Azores*. Its rate of motion, also, which has been continually decreasing, (and since its declining to the southward, rapidly,) is no longer to be detected by the reckonings of ships; although the higher temperature of its water is still perceptible. So that, as a *current*, it may be said to terminate, at ordinary times, at the western side of the Azores. But the great deposit of *sargasso* or *gulf-weed*, brought by that stream, out of the Gulf of Mexico, seems to show that a large portion of the Gulf-water passes insensibly to the southward, carrying with it a considerable degree of its higher temperature, and also the weed which it had brought forward.

The head of this vast mass of weed is situated in the very part where the stream bends to the S.E. and South, and begins to lose its force. It extends southward to latitude 19° or 20° N. It is, comparatively, narrow at first, but spreads out to six or seven degrees of longitude towards the tail; and lies the most close and compact between latitudes 37 and 21°. So that this deposit of weed, first discovered and named the *Sargasso-Sea*, by Columbus, extends in length more than 950 miles

from N. to S.; and appears to be, in a manner, stationary: at least, it has been so during 43 years that I attended to the subject; 1775 to 1818. This, of course, must be owing to some permanent cause; and that, probably, its being situated in the *Recipient* of the Gulf-Water. This is also the tract into which the *N.W. Branch* of the Equatorial current enters and appears to disperse; and seems to countenance the opinion that the streams have a general tendency towards the middle of the North-Atlantic.

The breadth, rate of motion, and temperature, of this celebrated stream, will be given in great detail in a particular Section hereafter. It may only be proper to mention in this place, that it is penned up within the space of 420 miles, in the *Strait of Florida;* which is doubtless the cause of its increased rate of motion lower down; and probably, also, *one cause* of keeping up the high level of the Gulf of Mexico. At Cape *Hatteras,* it is reported to have a breadth of 75 miles. But lower down, although the breadth of the *warm water* has been carefully noted, in several places, yet the breadth of the *running water* alone could not be obtained by the means possessed by a very intelligent and obliging inquirer. It is known, that, in the line between *Bermudas* and *Halifax,* it was between 140 and 150 miles, in Feb. 1820; and, in the May following, it was no less than 340: and these are the two extremes out of eight experiments. Probably, the experiment of February showed that of the *stream alone.* Three others,

nearly in the same place, and all within twenty days' space, in the month of May, 1821, gave respectively about 200, 240, and 250[1]. It is probable that, before the stream turns to the southward, it spreads to the breadth of 250 miles, from north to south; for the water in that place seems to be in motion the whole way across, at the rate of about 30 miles per day.

Its rate of motion has been noted as high as 120 miles per day, after passing the narrows of the strait; 48 to 60 at 1100 miles below its issue from the Mexican Gulf, and 30 or more after a course of nearly 3000 miles.

Its temperature on issuing from that gulf exceeds 86° at *maximum*; (or 7° higher than that of the Atlantic;) 81° after running 1100 miles; and at nearly 3000, 76° to 79°; and it carries 74° to the Azores. All these rates are at the *maximum* of each place, which may be reckoned to take place throughout July and August, except very far on its course, when it must be extended to September, as the Gulf-water arrives later. But even in December the temperature about Cape Hatteras was between 77° and 78°, or only 5° lower than in August and September.

6.—The ARCTIC CURRENT. [Chart II.]

A current from Greenland and the Arctic

[1] The length of these *transits*, respectively, was 146, 203, 238, and 249; but then they were not directly across the stream, but somewhat oblique.

Sea joins the Gulf-stream on the east of the Grand Bank of Newfoundland, somewhere about lat. 44°, and between the meridians of 44° and 47°. In the month of May its direction has been found to be between S.W. by S., and S., and its temperature 43° to 47°. The temperature taken not far to the eastward of it was 62° to 63°, and an easterly current of 30 miles, of the same water, (i. e. *Gulf-water*,) was found at a distance from the eastern edge of the S.W. by S. cold stream. *(See Chart.)* This is, doubtless, the current that brings down the ice from Greenland, &c. to the east of the Bank of Newfoundland, and ice has been seen in the line of this very current by different persons in different years.

The navigators to Newfoundland and New England place the junction of these currents in about lat. 41°, long. 49°, which shows how erroneous their ideas are on the subject.

There is also a smaller current that passes down the coast of Labrador, and eastern side of Newfoundland, and carries ice in sight of the coast, of which more will be said hereafter [1].

[1] THE FOLLOWING EXTRACT, on the ARCTIC CURRENT, &c. is from a letter addressed to the author, by Admiral *Sir John T. Duckworth*, Bart. and K.B. dated H. M. S. *Antelope*, Spithead, Nov. 9th, 1811.

"MY DEAR SIR,—During my summer excursion to Newfoundland, I have always kept in view the object of your friendly letter of the 29th of June, and from the disposition I have to promote the public weal, and to mark my private friendship, I regret that my inquiries have not tended to a clearer elucidation of the set of the various currents you mention, but such as they are I will

7.—THE NORTH-ATLANTIC CURRENT. [INDEX CHART.]

The next current to be considered is that to the northward of the Gulf-stream, or latitude 44°, and ranging along the head of the North-Atlantic, between Labrador and Newfoundland on the one hand, and the British Islands with France on the other.

This current is so weak that it would scarcely be perceptible, were it not for its bringing various parts of wrecks, and floats purposely thrown on it from ships on the passage, which by their great equality of motion, and general direction of course to the

detail, and shall feel truly gratified if, with your superior discernment, you can select any thing worth notice.

"*The extensive stream which sets to the southward,* out of Hudson's Bay and Davis's Strait, takes a S. by E. direction along the east coast of Newfoundland, at about 1½ knot an hour in the summer; in the autumn it increases its rate nearly a knot, and continues so till the month of May, when the islands of ice are most abundant on the coast; but no doubt the current is influenced, in some degree, by the direction of the wind.—*Part of it seems to enter the Strait of Belle Isle,* and joins the Gulf of St. Lawrence. At a few leagues off Cape Race, [the S.E. Cape of Newfoundland,] the Hudson's Bay stream seems to join the Gulf of St. Lawrence stream; a part sets up along shore, to the *westward,* rounding the bays in its course. This last I take to be more of an *eddy* than a general set of the current. At about 41° or 40° of latitude, and 49° of longitude, the Mexican [Gulf] stream is generally considered to form a junction;—when the outsets from the American gulfs and rivers may alter its direction; and, probably the meeting of the whole causes the grand bank and numerous other banks on the American coast."

We shall have occasion to advert to this letter when we come to the *Appendix.*—ED.

eastward, prove that the same causes must generally prevail. The floating substances that are committed to the sea to the north of lat. 44° arrive at some point between the Orkneys and Cape Finisterre, and those to the south of 44°, commonly in the West-Indian Seas. On this point much more will be said in the sequel and Appendix.

By the slowness and equable motion of the floats, the direction, or obliquities, of those that arrive, correspond very much with the prevalent winds from the western and south-western boards. One may, therefore, refer the general motion to the drift of such winds.

But there evidently seems to be an accumulation of water towards the *eastern and south-eastern parts of this tract*, and which, together with some influx from the Polar Sea, appear to give rise to the *North-African Current*, now to be described.

8.—The NORTH-AFRICAN and GUINEA CURRENT.

[Chart I.]

It has just been said that the last-mentioned wind and current must, necessarily, produce an accumulation which the Arctic waters must have a tendency to increase. The consequence of the accumulation must be the running off of the superficial waters towards the S.E.

The stream of current now denominated the *North-African and Guinea Current*, is that which, originating in our parallels[1] runs to the south-

[1] That is, between 45° and 53° of latitude, and between the meridians of the coast of Portugal and the Azores.

eastward and southward as far as the coast of Guinea and the Bight of Benin; often approaching the shores and being augmented in its way by drift-currents, so as to become a powerful stream.

The origin of this current may be traced chiefly to the same cause with that of the stream which passes out of the South-Atlantic into the Indian Ocean, round the Cape of Good Hope, and to the south of the Lagullas stream: and also to that which, in the Indian Ocean, passes along the south coast of Australia: namely, the *eastern drift*, occasioned by the prevalent westerly winds; by which an accumulation of water is caused in the *eastern quarter* of the *head* of the North-Atlantic.

To *this* cause of accumulation another may be added; which is, the influx of water from the *Polar* or *Arctic Sea*. For, although this enters chiefly towards the quarters of America and Greenland, it must necessarily add to the volume of water.

The arrival of this northern water may perhaps be one cause of *refrigerating* the Atlantic current; for it was found that, in the latitude of about 21° N., at the end of May, and under a vertical sun, that the temperature of the current water was only 69°, which is that of latitude 40° in July. So that, probably, the water of the current may be several degrees colder than that of the natural temperature of the climate.

A third cause of accumulation, it would appear, sometimes happens; that is, by the extension of the *northern* branch of the *Gulf-stream* of Florida

home to the coasts of Europe, although it appears generally to go no farther than to the Azores[1].

This stream is exceedingly wide; for it appears to occupy the greatest part of the space between Cape Finisterre and the Western Islands: at least all that body of water appears to be in motion to the south or south-east: the *outer* part going more southerly, and the part toward the land more *easterly*. More will be said on this head hereafter.

At the very commencement of this current it presents a very curious and interesting phenomenon. *It sends out a branch to the* S.E., which passes into the southern part of the Bay of Biscay; and, after coasting the northern shore of Spain, turns to the north and N.W. along the coast of France; and, shooting across the mouths of the English and Irish Channels, bends round to the west, and thence through all the intermediate points to the south-east; and, falling again into the original

[1] Dr. Franklin, Captain Beaufort, Captain Tuckey, (or Mr. Fitzmaurice), Dr. Davy, and the American Commodore Truxton, have all noted the temperature of the sea-water in their courses through the Atlantic, and particularly between the meridians of the Azores and the coast of Europe, between the parallels of 34° and 50°. The temperatures were never higher than as natural to the season and parallel.

But Dr. Franklin, in a preceding year, found the temperature along the parallel of 45°, from the meridian of the Azores to a point far within the Bay of Biscay, to be several degrees higher than *par*. In effect, at the end of November two degrees higher than the maximum in summer, as he had himself previously experienced.

current, performs a complete rotation between Spain, France, and the Atlantic at large. It is the outer or N.E. side of this vortex which, by a kind of centrifugal motion, flies off to the N.W. and across the two Channels, and forms the current which so often places ships in danger near Scilly[1].

As the main stream which supplies this vortex depends, in respect of its volume, on contingencies, it must necessarily happen, that the subsidiary one must also be subject to changes; at certain times operating strongly, at others weakly and almost imperceptibly; but no doubt always in existence in some degree, although not considerable enough to manifest itself. It is felt most strongly *after strong westerly or S.W. winds;* which may be supposed to increase the volume of water which has been regarded above as the *reservoir* of the North-Atlantic current; and thereby quickening the motion of the circular current derived from it.

Reverting to the southerly stream, which originates as described, it will be observed, of course, to vary in its breadth and velocity, at different times, according to the force or continuance of the westerly winds and the quantity of Polar water accruing. It appears to extend in breadth, at times, to within a few degrees of longitude of the Azores, and it is to be remarked, that the western

[1] This is the current which was first explained and made known by Major Rennell, in 1793, as shown in the Appendix hereafter.—ED.

part of the stream runs very much *southwardly ;* the eastern part very much *eastwardly ;* as being influenced by the indraught of the Mediterranean, through the Strait of Gibraltar : for it appears that the general surface of the sea, from the parallel of Cape Finisterre to latitude 30°, and as far to the westward as longitude 20° W., is in motion towards the Strait, in order to supply the great waste of the Mediterranean by evaporation ; that sea being of a higher temperature than the Atlantic, by several degrees. It is also to be remarked that this stream, coming from a colder climate than those it passes through, is considerably colder than what may be considered as the *still* water ; and the difference becomes, of course, greater and greater, until there has been found eight degrees of difference when approaching the parallel of the Cape Verde Islands.

According to the above statement it happens that, a ship sailing from our parallels, southward, will find, generally, between the Bay of Biscay and Madeira, in the usual line of course, a south-easterly current, and which is more easterly as it approaches the parallel of the Strait of Gibraltar, where it is commonly due east[1]. The rate of motion of this current varies from 12 to 20 miles per day. I have an example of 140 miles in eight days, in one of his Majesty's ships ; equal to $17\frac{1}{2}$ per day ; and in another of twelve ; and,

[1] It is this portion of the current which has carried so many trading vessels on the coast of the Desert.

in a well kept East-India ship's journal, 170 miles in nine days, to Madeira: and, in a recent instance, a ship was carried 99 miles to the *eastward* in eight days.

In the usual line from Madeira, south-westward, to the *sight* of St. Antonio, the north-westernmost of the Cape Verde Islands, the current almost always sets to the south-eastward as far as the latitude of 25° N., when it will be found to be south-westward or *more westerly*, obeying the general trade-wind. Indeed the S.W. current commences in twenty-eight degrees of latitude, or even farther northward, in that part of the ocean lying to the westward of the line of course from Madeira to St. Antonio: but the effect of the draught *towards the strait* appears to operate, to a great extent, southward. Whatever may be the cause, such is the effect.

I have now brought you to the Cape Verde Islands, by what is called the *outer* passage, and which is to be preferred, at all seasons, for ships bound to the southward: because, even when the S.W. *monsoon* prevails, between latitude 15° and the equator, and you are compelled to go to the eastward (between June and September) you will be farther to windward, and will have a more steady wind, and favourable current to the S.E., than near the coast of Sierra Leon, &c. But, if you are bound *to Sierra Leon*, you will, of course, keep a southerly course, from the Canary Islands (Palma and Ferro), and you will find a favourable current the whole way to *Sierra Leon;* but not a

regular southerly current till you get past the parallel of 25° N. From thence it appears to be one regular *southerly* current; that is, varying only a little to the east or west of south, and occasionally influenced by the form of the coasts of Africa; for instance, to a very considerable distance into the ocean, the lands of Cape Blanco and of Cape Verde produce an obliquity in the current to the westward of south.

Southward of Cape Roxo the current turns more to the eastward of south, influenced no doubt by the change in the direction of the coast: but I possess no information relating to the subject more than in the line ordinarily pursued by the East-India ships; and which, during the S.W. winds, are compelled to run to the eastward. Within a line drawn from the Bissagos to Sherbro I have no kind of information respecting currents[1].

Although you will, at this season, carry a fair wind with you to *Sierra Leon*, yet it may be proper to inform you that, within the space, *lengthwise*, between Cape Verde and Cape Mesurado, and in certain places, to the extent of seventy leagues off shore, (fifty off Sierra Leon,)

[1] This portion of the author's manuscript appears in the form of instructions to a friend, inviting him to future investigation.

The *Baron Roussin* says, that the usual prevailing currents on the coast to the northward of Cape Roxo, are found to be completely changed on passing this cape. They have here no longer one only direction; and, in all the channels of the Bissagos, are superseded by tides, which are more or less regular; and, in some channels, perfectly so.—Ed.

a regular change of winds and currents takes place, according to the seasons; that is to say, a N.E. or north wind and S.E. current from September to June; and, in the rest of the year, S.W. winds and N.E. or northerly currents. In effect, a *monsoon;* and this extends, in respect of the winds, nearly through the whole space between the two continents.

Returning again to the current, said to bend somewhat more to the S.E. beyond *Cape Roxo*, the main body of it continues its course, gradually bending more and more to the south-eastward, till about the latitude of 5° N. it turns decisively to the east; and, running with considerable rapidity, sometimes at the rate of two knots, it ranges along the whole coast of Guinea, until it is partly dissipated in the Bight of Benin, &c., and partly stopped a-head by the equatorial current, as already shown (page 22). The *Guinea Current* may be taken at sixty leagues in breadth: its greatest rapidity is during the season of S.W. winds in the sea lying west of Sierra Leon and south of the Cape Verde Islands.

It has been said that periodical winds (in other words, a *monsoon*) prevail on this coast. It is also known, from the journals of the Grenville and Royal Charlotte, E. I. M. both of which coasted the western shore of Guinea; that is, between Cape Verde and Cape Mesurada, a space of about 200 leagues, the former in *June*, the latter in *January*, that, during the former period, which was that of the *northerly* winds, a current, which

might be called the *Inner current*, from reasons that will make themselves appear, ran to the *south-eastward;* but in the season of *southerly* winds the contrary: that is, in both cases, the current ran to *leeward;* and, also, nearly along shore. The *Inner* current then, in the season of northerly winds, is, of course, blended with, and becomes the *eastern border* of, the *great* S.E. current from the North-Atlantic, which I have just described as passing along the coast of Guinea, and occupying a space of three degrees in breadth. But, in the season of southerly winds, this *Inner* current runs contrary to the great S.E. current, in the nature of an *eddy*, between *that* and the shore: and, it may be concluded, does not extend far out from the latter.

This closes our circle of *consecutive* currents, or round, to the commencement of the Equatorial current in the Bay of Benin, &c.

2.—The NORTH-WEST BRANCH of the EQUATORIAL STREAM. [Chart I.]

The N.W. branch of the Equatorial Current is traced to the N.W. by N. and into the *Sargasso Sea* or Sea of Weeds, the recipient of the Gulf-stream, as shown in Chart I. of the Atlantic Ocean.

This branch is much the smaller of the two, and becomes very weak before it attains the 18th degree of latitude. It is sometimes perceptible as far north as 20°, but seems to depend on the state of the Gulf and Equatorial streams; probably most on the former.

10.—The BRASIL or S.W. EQUATORIAL CURRENT.
[Charts I. and II.]

This, as we have already shown, is a stream which separates from the Grand Equatorial current at Cape St. Roque, the N.E. promontory of South-America, and thence pursues its way, southerly, along the eastern side of Brasil, receiving vast supplies in its way from the drift current of the S.E. trade, and increasing so as to be no less than eight hundred miles broad in latitude 25° S., and in velocity from 30 to 10 miles

This stream owes its existence to being kept up in the full form in which it appears so long, to the drift waters which it receives from the S.E. trade.

The Brasil Current, to the extent of lat. 24° S., had thirty miles of velocity daily, according to two reports. Twenty miles by another, to latitude 27°, and fifteen to latitude 32°.

It appears to continue to Cape Horn itself, and even to turn round it into the Pacific Ocean.

Another current, of greater body and strength, passes outside the Brasil current, being the effect of the general westerly wind, between the Pacific and Southern-Atlantic Oceans.

Beyond the line of the S.E. trade, this stream detaches a branch to the east and S.E. (afterwards the *Connecting Current*) which helps to increase the current of the prevalent winds between the parallels of 30° and 40° S., so as finally to form a considerable stream.

11.—The CONNECTING CURRENT of the SOUTH-ATLANTIC, with the PACIFIC and INDIAN OCEANS, ROUND THE CAPE OF GOOD HOPE AND CAPE HORN.

[Charts I. III. and IV.]

This stream arises from two sources. The first and most powerful is a portion of the *drift* water from the S.E. trade, detaching itself from the Brasil current; and the other the *drift* water of the prevalent westerly winds beyond the trades.

By the time of its arrival opposite to the Cape of Good Hope, to the southward of which it passes at the distance of about 150 miles, it has acquired a breadth more than equal to the same extent, or about 180, as appears by Captain Cook's report, who crossed it directly, from south to north, opposite the tail of the Bank of Lagullas, entering in latitude 41° S., and leaving it on entering into the Lagullas current, in latitude 37° 20′. (*See Chart* III). These currents evidently jostle each other, a large portion of each being turned back; that of the Lagullas or Indian current being turned eastward, and traceable, by its division and temperature, forty degrees of longitude into the Indian Ocean, through the parallels between 35° and 40°; and that from the Atlantic being turned to the N.W., mixing with the remainder of the Lagullas stream, which comes round the Bank of Lagullas and Cape of Good Hope. (*See Chart* IV.)

More will be said on this subject in its place, under "Lagullas Bank and Current."

12.—GENERAL ILLUSTRATION OF THE WHOLE.
[INDEX CHART.]

In the pursuit of our inquiry, it is proper to begin in the South-Atlantic Ocean; as *that* may be considered *as the highest up, in the stream* which commences at the Cape of Good Hope: since the *general* motion of the waters is from thence, towards the northern part of the North-Atlantic.

SOUTH-ATLANTIC CURRENT.—The current which sweeps round that celebrated promontory, (or rather round the Bank of *Lagullas*, which projects from it, and gives name to the current,) is formed out of the waters of the Indian Ocean, which are impelled, by the S.E. trade-wind, towards Madagascar and the S.E. coast of Africa; where they accumulate, and form a broad and rapid stream. Having rounded the bank, it proceeds to the north-west, up the South-Atlantic; and is augmented, at its very entrance, by a large portion of an easterly stream, which crosses over from the coast of South-America; and of which more will be said presently. Having proceeded several degrees to the N.W. and N., the Lagullas current merges in the general current caused by the S.E. trade-wind, in the South-Atlantic. Here it must be noted, that, of this general current, or rather *drift*, occasioned by the S.E. trade-wind, over the whole surface of the South Atlantic, that portion of it which lies towards the African shore; and generally throughout the *Ethiopic Sea*, has *a more northerly direction* than that in the middle and western parts of the

same ocean; owing to the more southerly direction of the reigning winds. Accordingly, the waters in that quarter are both quickened in their progress, by the agency of the land[1], and impelled in a direction more immediately towards the Equator; in which neighbourhood they *partly meet, and partly impinge on the flank* of the current of *Guinea;* a powerful stream from the North-Atlantic, which, running eastward, skirts the whole coast of Guinea, from Sierra Leon to the *Bight* of *Biafra;* and occasionally extends southward nearly to five degrees south of the Equator.

The South-Atlantic current, thus opposed by that of Guinea, is turned to the westward, and by degrees becomes the *head* of a still more powerful stream, under the name of the *Equatorial current;* so called from its keeping nearly to the Equator, during thirty-five degrees of longitude, across the Atlantic: *brushing*, and sometimes *pressing* on, the *Guinea current*, as far as their *opposite* and *parallel* courses lie together.

The Guinea current seems, at common times, to disperse itself in the wide space formed by the two great Bays of *Benin* and *Biafra*, when checked by the current from the south; and may be said *then* to *die a natural death* there. But in the seasons when it crosses the Equator, and is in full force, it is probable that a part of its waters may mix with, and augment, the Equatorial stream.

The difference of *temperature* between the Guinea

[1] This will be explained in the sequel.

current, and that from the south, at their meeting, is considerable: the former, heated by a long course through a warm region; the other cool, as coming from a distant southern latitude. The Equatorial current, also, through its whole course, is every where of a lower temperature than the sea on both sides of it, being either formed of, or receiving, fresh supplies during its course, from cooler regions: and, where the Guinea and Equatorial currents pass each other, the Equator is generally the boundary between the two different temperatures.

The Equatorial Stream, in its way to the westward, being thus gradually augmented by the supplies poured into it by the S.E. trade-wind, becomes, at last, a stream of 400 to 450 miles in breadth; and, at times, of great rapidity. This is the stream which sometimes hurries ships so far to the westward, that they are not able to weather the N.E. promontory of Brasil; until they have tacked and stood a great way to the north-eastward[1].

About midway between the approximating parts of the two continents (where the ocean is about

[1] There are also *Equatorial currents* in the Indian and Pacific Oceans. That of the Indian must, of course, fluctuate, as being subject to periodical and opposite winds. From the paucity of materials, for a description of the currents in the Pacific Ocean, one cannot pronounce what the general state of things is, respecting them; but it clearly appears, that there is a westerly current between the tropics, *there*, as in the Atlantic; and the rate, from 11 to 15 miles *per* day, at a medium, across the torrid zone, in the centre of the Pacific. And, near the Equator, from 32 to 44 and 49 miles.

1540 geographic miles across) the Equatorial current divides itself into two branches; which diverge from each other almost at right angles: for the one which ought still to be called the Equatorial stream, turns from a general westerly course, to W.S.W. and S.W. by W., the other to N.W. by N. The former is again *subdivided*, by the intervention of the land of Brasil; when the northernmost of those subdivisions (which is the proper *Equatorial* stream) runs to the W.N.W. and N.W., along the *northern* shore of Brasil, towards the *West-Indies;* the other, falling on the *eastern* coast of Brasil, to the southward of Cape St. Augustin, is turned to the southward; receiving, in its progress, the waters impelled to the westward by the S.E. trade-wind, (or rather *easterly* trade, in this quarter,) finally becomes a great stream. The reader will perceive, that the effect produced here, by the trade-wind, is exactly similar to that which produces the *Lagullas* current, in the Indian Sea: and there will be occasion to remark the like circumstances elsewhere [1].

Brasil Current.—This stream, which the author will beg leave to call the *Brasil Current*, also subdivides, after passing out of the limits of the S.E. trade-wind: one part, and that very much the largest, is known to continue its course to the S.W., as far as the southern extreme of South-

[1] Mr. Robins, the writer of Anson's Voyage, in the elegant form in which it at present appears, observed very justly, that the current along the coasts of Brasil and Patagonia, must be "occasioned by the water accumulated by the S.E. trade-wind."

America: the other, turning to the eastward, between the parallels of 30° and 40° S., and being augmented in its progress by a large portion of the returning drift, caused by the S.E. portion of the trade-wind, as well as by *that* occasioned by the prevalent westerly winds, becomes a wide stream, previous to its *meeting* that of Lagullas, in its course round the bank, to the north-westward. The current in question, may, perhaps, be properly named *the Southern Connecting Current*.

The opposition presented by the Lagullas current, causes the current from the side of America to divide: the northern part turning to the North and N.W., with the former, and proceeding with it, *up* the South-Atlantic: but the other part, bending to the S.E., and encircling in its way the Lagullas current, passes into the Indian Ocean: and, regaining its easterly direction, after passing round the Bank, is felt at forty degrees of longitude, or nearly 2000 miles, east of the Cape of Good Hope.

Since, then, the *Brasil* and *Connecting* currents are composed of South-Atlantic waters, and that a portion of their streams join and proceed up the South-Atlantic, with the Lagullas stream, it is obvious that a part of the South-Atlantic waters do actually make a *complete* circuit in that ocean.

* * * * *

Returning to the Equatorial current, at Cape St. Roque, or the N.E. promontory of Brasil;—this current continues its course along the northern coast of that country and of Guyana; receiving a fresh impulse from the waters impelled westward by the

north-east (or rather in these regions, *easterly*) trade-wind.

GULF-STREAM.—The next stream of current to be considered, is that of Florida, or the *Gulf-stream*, which issues with great velocity from the *Mexican* Sea; and which (together, we conclude, with the Caribbean Sea, adjoining to it,) is supposed to have a much more elevated level than the Atlantic Ocean.

Different opinions have appeared respecting the *cause* of this elevation. Amongst others, that of the influx of river water; but the comparative paucity of that supply, with the copiousness of the discharge, at once sets this opinion aside[1]. Another, and by far the most prevalent, opinion is, that it is produced by the *inset* of the continuation of the Equatorial current: but it is obvious that a current cannot form a *head of water*, *higher*

[1] The BLACK SEA receives a great number of large rivers; as the *Danube*, *Borysthenes*, *Don*, *Nieper*, *Phasis;* together with numerous other streams, some of them of considerable size; as the *Kuban*, *Boug*, &c. Yet its discharge, through the Canal of Constantinople, is no more than half a mile in breadth; and runs at the rate of three miles *per* hour. The volume of river water received into the Sea of Mexico bears no proportion to the other; and its evaporation is, of course, very much greater; as well from its greater expanse as the warmth of the climate.

The *Missisipi* itself, although the *drain* of so vast a region, is no more than about half a mile (900 yards) in breadth, at New Orleans; where it is 15 fathoms in depth, and having a current of two miles per hour. At its *outfall*, it is only 12 feet deep over the *Bar*. The Gulf-stream is $32\frac{1}{2}$ geographic miles broad, in the narrowest part, and runs at the rate of 4 to 5 miles per hour.

than itself: as at the utmost, it can run only on a *level plane*.

The author is of opinion that the cause of this high level may be the operation of the N.E. trade-wind, by forcing the surface of the *wide expanse* of the western part of the Atlantic into a space *comparatively narrow*; and thereby pressing it up into a more elevated level; through the want of lateral space.

In order to place this matter in a clear light, it will be necessary to refer to what has already appeared, respecting the operation of the trade-winds, on the surface of other parts of the ocean; to show that, although the same original cause produces the same effect in the *first instance*, yet that circumstances may subsequently arise to change, totally, the result.

The power of the S.E. trade-wind, in impelling the surface of the South-Atlantic towards the eastern coast of Brasil; as well as in the Indian Ocean, towards the eastern coasts of Africa and of Madagascar; is proved by the existence of the Brasil and the Lagullas, or Cape of Good-Hope, currents. By close analogy, the same effect, in the first instance, ought to be produced by the N.E. trade-wind, in the North-Atlantic.

The water impelled by the S.E. trade-wind, proceeds nearly in parallel lines, preserving, generally, the same level, and then impinging, nearly at right angles, on a straight open shore, where it accumulates into vast streams, and runs off along shore. But it is not so with the water impelled,

by the N.E. trade-wind, into the *South-American* and *West-Indian* Seas. A slight view of the chart will show that the coasts of Brasil and Guyana present a *very oblique* line of direction to that of the passing *stratum* of water; and are constantly contracting its breadth, more and more: so that, on its arrival at the *Caribbean* Sea, it is reduced to *one half* of its original breadth at the N.E. promontory of Brasil; and, as the water is impelled in *straight* lines, in the South-Atlantic, it may be said to proceed *here* in converging lines.

Is not this, then, a solution of the question, respecting the cause of the elevated level of the *Sea* of *Mexico?* A vast expanse of water is driven, gradually, into a much narrower space; and, wanting *lateral* room, is compelled to raise its level.

There is a case, somewhat in point to this, where the waters driven into the *Ethiopian* Sea, during the season of S.W. winds, have, in running off, increased the rapidity of the *Equatorial* current to $3\frac{1}{4}$ miles, in the month of July [1]. On a smaller scale, the effects produced by the waves of tide, in the *Bristol* Channel, the Bay of *Fundy*, the Gulf of *Cambay*, &c. are pretty similar.

When the subject of the Gulf-stream is hereafter considered in detail, under a separate head, it will be shown, by various circumstances, that *a reigning*

[1] These winds are the cause of the strong currents that prevail about the Equator, and to some degrees south of it, when the sun has great northern declination.

wind, at least, affects the velocity of the stream; even if it be not the sole agent. It may be added here, that the nature of the currents which set into and out of the Sea of Mexico, agree better to the system which supposes a high level kept up by the winds, than by an *inset* produced alone by a current.

The GULF-STREAM is projected with so much force, as, at *ordinary times*, to reach the *Azores;* a course of about 3000 geographic miles; carrying with it a portion of the warmth of the high temperature of the Sea of Mexico: and this warmth has been *occasionally* felt, (as already shown,) in the Bay of Biscay, a distance of 4000 such miles. These differences of distance may, probably, be ascribed to the different velocities of the stream at the *outfall;* which ordinarily varies from *five* to *two and a half* miles per hour.

The stream is well known to range, generally, along the coast of North-America, from *Florida* to a point beyond the mouth of the River Delaware; when the banks of *Nantucket*, &c. adjacent to that coast, *turn it off shore* to the eastward, and even to the south of east. After this, it recovers a more northwardly course, and runs between *East* and E.N.E.; spreading to a vast breadth; the southern part appearing to deviate to the east of south, whilst the northern part runs decisively to the northward of east; preserving its former course. But it is the northern part only that is known in *detail*, to the author. It is however certain, that the *warm water* of the Gulf-stream extends from

latitude 34° to 44° north: for the experiments of Dr. Franklin, and of Captain Beaufort, go to a proof of it. The northern part of the stream is traced on a course of about E. 20° N., to the longitude of 45° west, in latitude 44°; which we believe is the highest parallel it is known to arrive at, in that quarter: and between 45° and 40° of longitude it bends to the south-east and south; and seems, at ordinary times, to terminate at the *Azores:* to which meridian, or about 30° W., its warm water is generally found to extend.

Out of six reports in different years, on the temperature of the ocean, between the meridian of the Azores and the coasts of Europe, only one traces the warm water to the eastward of 30°, the other five report it cold, generally, to the eastward of the *Azores*: and it should be remarked, that Dr. Franklin, who marked the extent of the warm water eastward to the Bay of Biscay, was also one of the persons who found cold water in the same position in other years.

It may be remarked, that when the Gulf-stream came so far eastward as to join the current running from our parallels, towards the Equator and Guinea, the *circle of waters, round the North-Atlantic,* would *then* be as complete as we have stated that in the South-Atlantic to be, *at all times:* but this appears to happen but seldom.

THE ARCTIC CURRENT.—A current from Greenland and Davis' Strait, as already noticed, joins the Gulf-stream on the east side of the great Bank of Newfoundland; bringing the ice from those re-

gions into the warm water of the Gulf-stream, where it soon disappears. Other currents, from the Arctic Seas, prevail during the summer; when the stream receives a vast mass of water, from melted ice and snow, on the Arctic lands[1].

NORTH-ATLANTIC CURRENT.—The next current which has been defined is that to the *northward* of the Gulf-stream, in the line between America and Europe; which sea may perhaps be termed *the Head of the Atlantic*. This is a slow motion to the eastward; probably the effect of prevalent westerly winds, which impel the surface much more to the *east* than other winds to any of the other quarters. This effect is, however, palpably felt by the navigators between Europe and the northern parts of North America; who all agree that their reckonings give a much greater number of miles outwards than homewards.

This *drift* current eastward must, of necessity, produce an accumulation of water in the eastern part of this sea; and which the Arctic waters must have a tendency to increase: and the consequence of the accumulations must be, the running off of the superincumbent waters, towards the south and south-east; since these waters themselves flow from the west and north, and the eastern quarter is shut up by land. Here then is the commencement of that remarkable stream, which flows continuously, though irregularly, in point of direc-

[1] And probably water also from the Pacific Ocean, through Behring's Strait. More will be said on the subject in the Appendix, hereafter.

tion, from our parallels to the coast of *Guinea* and *Bight* of *Biafra*, at all times; and in some seasons, to five degrees south of the Equator.

This motion of the sea gives birth to the current which circulates round the Bay of Biscay, and sometimes places ships in danger in the parallel of the Scilly Islands. It also helps to supply the waste, by evaporation, in the Mediterranean. It carries with it the cool temperature of its place of origin, so that, to a point beyond the Cape Verde Islands, and with a vertical sun, it is still several degrees lower than the natural temperature of the parallel and season. But then receiving a large accession of water from the westward, the collective mass, now become the GUINEA CURRENT, rises in temperature, at once, several degrees.

As it was necessary to distinguish each stream of current by a particular name, the Author has ventured to name the latter the *North-African and Guinea Current*. The termination of the Guinea current, and its connexion with the Equatorial, have already been explained.

N.W. EQUATORIAL STREAM.—There remains to be mentioned, the *North-west* Branch of the *Equatorial stream*, which separates from its parent stream nearly midway between the two continents; and precisely at the Equator itself. It takes nearly a N.W. by N. course, and is known to have a breadth of 180 to 200 miles, at its separation; but afterwards spreads out to more than 300. And as, beyond these limits, to the westward, the currents take a *westerly* direction, one may conclude

that the breadth of the N.W. stream does not exceed the above dimensions. It appears to run, *at all times*, to 20° of north latitude; but very commonly to 25°; and sometimes much farther, but bending more to the northward [1].

As it runs so near the direction which the N.E. trade-wind generally compels ships to sail in, on their way northward to Europe, it affords an useful help: and to ships bound to America direct, and which make the N.E. trade a fair wind, it may *at all times* be made useful, to lat. 20° north.

By its position, it operates as a *catch-water drain*, to that part of the N.E. *drift* current whose course *follows* it obliquely [2]; but the part which *meets* it obliquely it turns aside to the south-east, and thence into the Guinea current.

SARGASSO SEA.—The N.W. stream just described, terminates in the *Sea* of *Sargasso*, first noticed by

[1] Low rocky islets, named by some St. Pedro's, and by others St. Paul's, lie in a position which may possibly have a share in determining the *place* of separation; if it can be supposed to have a *base of sufficient extent*, under water. The effects of the *Nantucket* and *Lagullas* banks, on the *Florida* and *Lagullas* streams, have already been remarked.

[2] This is a drain carried along, or near, the base of an *upland* tract, bordered by a very *low* country, already incommoded with its own *superabundant* waters. Its use is to receive the waters that drain from the upland, and send them off, clear of the tract below it.

The *Kuban* and *Terek* rivers on the north, and the Faz (or *Phasis*) and Kur (*Cyrus*), on the south, may be reckoned natural *catch-water drains* to the region of *Caucasus*, between the Caspian and Black Seas.

Columbus, in which the *weed* brought by the Gulf-stream is deposited; and which tract the Author regards as the *recipient* of the warm waters of that stream: and concerning which more will be said in the sequel.

The streams above mentioned hold their courses, generally, at too great a distance from land, to be affected, in any degree, by the tides.

Such of the above streams, as require a more particular discussion, will be treated of, separately, hereafter.

13.—On the CAUSES and EFFECTS of the DIFFERENT CURRENTS.

The Author now proceeds to the detail of the immediate causes which produce the different kinds of currents, and their apparently irregular courses.

It has been stated above, that, in the region of the trade-winds, the whole surface of the sea, generally speaking, is converted into a slow current, moving to *leeward:* and this progress appears to continue, without change of direction or considerable increase of velocity, until some obstacle intervenes to arrest its progress; and, in consequence, to produce, as they successively arrive, an accumulation of its parts into a collective mass; which mass, running off, by means of its own gravity, and taking the direction imposed on it by the obstacle, becomes a *stream* of current, and, in many cases, a *powerful stream.*

Whether the obstacle be *a line of sea-coast*, a

bank of soundings in the ocean, or a *stream* of *current* already formed in a distant quarter, by the process which has been just described; the effect will be nearly the same: for although, as in the latter instance, the obstacle be a body composed of yielding materials, yet, *as a body*, it will preserve its general form and place; and will operate on the impinging current, in a great degree, much the same as land or a bank would do; of which several instances occur in the charts[1].

Here it may be proper to distinguish the two kinds of current, by different and significant names.

The FIRST, being merely the effect of the wind on the surface of the water, may not improperly be termed the DRIFT current: since the term *drift* appears not only to be *proper* to it; but is already in use, as a technical term, amongst seamen, to express the motion of any *body* which is *casually driven by the force of the wind* alone. And

The SECOND, whose *elementary parts* consist of the mass of waters collected by the former, and thrown into *one bed*, through which it pursues its way, like a *vast river*, through the ocean; may

[1] Much the same course takes place in the INDIAN OCEAN, where the water, driven to the N.W. and W.N.W. by the S.E. trade-wind, is opposed by the coast of Madagascar and the S.E. coast of Africa; whence, hurrying to the S.W. it forms two streams, (one *within*, the other *without*, the island,) which unite and fall with great force on the African coast near *Algoa Bay* and *Point Natal;* where it has been known to run at the rate of 4½ miles per hour, for 24 hours together; and very frequently 3 or 4.

perhaps, not improperly, be termed the STREAM current.

Nothing can well differ more, in their nature and description, than these two kinds of current, although they are generally confounded together; probably from the want of such observations and remarks, as experience, joined to a comparison of facts, could alone furnish: for the subject, as a system, is confessedly *new*. The one of these currents, being formed by the passing of a general wind over the surface, is, of course, shallow and slow, and *can run in no other direction than to leeward:* whilst the other is, in effect, an OCEANIC RIVER; and, as it may happen, from 50 to 250 miles in breadth; and so profound as to be sometimes *obstructed*, sometimes *turned aside*, by *banks*, which do not rise within 40 or 50 fathoms of the surface of the sea[1]; and proceeds with a rapidity of motion that sometimes exceeds that of capital rivers, in their ordinary navigable state. Consequently, these cannot be influenced, or operated on, in respect of their main body, by the wind, like the drift currents; although their borders may, in some degree. Some of these streams preserve their courses to a distance that is scarcely credible; so as even to occasion a mutual *interchange of waters* between distant parts of adjacent

[1] For instance, the Gulf-stream, by St. George's Bank and Nantucket Bank: and the stream of Lagullas by the bank of that name.

This may suffice for an idea of the nature and description of the DRIFT and STREAM CURRENTS.

oceans, as between the Indian Ocean and the Atlantics, round the Cape of Good-Hope. So that the waters which wash the coasts of *Arabia* and of *South-Africa* may chance to wash, in succession, those of *South* and of *North-America*, the *Azores*, and, occasionally, those of Europe also. The northern *Polar Sea*, (and probably the *Pacific* also, through it,) sends water into the *North-Atlantic*: but this latter ocean *receives* supplies *alone*, without *imparting* water to other seas; (its own *adjuncts* excepted;) being itself constantly *deficient* from its supplying the waste of the Mediterranean, and by evaporation of the heated waters poured forth by the Gulf-stream of Florida.

In effect, so extensive is the chain of communication effected by these currents, that, in one instance, partly by the *momentum* originally acquired, and partly by new powers, adding fresh strength to the stream, (or it may be said, renovating it,) a floating body might be carried by one and the same thread of current, from the entrance of the *Red Sea* to the *Azores*, at all times; and sometimes home to the shores of Europe!

Were we to suppose a globe *covered with water*, one might expect that the opposite trade-winds would impel the surface waters, subject to their operation, obliquely and gently from each side, towards the Equator; where the passing waters would meet, accumulate, and form a broad stream, somewhat in the nature of the Equatorial current, in the Atlantic, but more regular, running to the westward, along both sides of the Equator, round

and round the globe for ever. But as our globe is *terraqueous*, and the land broken into an endless variety of forms and positions, those gently moving surfaces, which would, in the other case, have flowed so smoothly and uninterruptedly, are here interrupted in various ways; and, accumulating into different streams, are projected in such directions, as the positions of the several obstacles necessarily produce. And beyond the region of the trade-winds, one must suppose that comparatively slow easterly current, produced by the prevalent westerly winds, would, on the globe of water, circulate round and round the temperate zones; instead of being accumulated, and turned to the north or south, as on our terraqueous globe.

If the reader casts an eye over the INDEX MAP to the system of ATLANTIC CURRENTS, he will perceive that the motions of the different streams accord with the above principle, where it is left to operate freely, or even in degrees. For, within the region of the trade-winds, in both Atlantics, the movements of the general surface, (in other words the *drift currents*) are to the westward, obeying the reigning winds. That the coasts of the two Americas, each respectively, opposing this movement, turn the accumulated waters, as they arrive, the one to the north, *i. e.* the *Gulf-stream*, the other to the south, the *Brasil current*, whence, in whole or in part, they turn back again to the eastward, through the tracts of *variable winds*; receiving, in addition, the waters impelled in that general direction, by the prevalent westerly winds.

Also that, in the neighbourhood of the coasts of the old continents, in both Atlantics, within the range of the trade-winds, the waters flow more directly towards the Equator: here again obeying the general winds, (whose directions in those quarters, as we have seen above, approach much nearer to those of the coast, by which they are influenced, than in the ocean at large;) and one of those streams being augmented by the waters from the Polar Sea; the other by those of the Indian Ocean, round Cape Lagullas, and the Cape of Good-Hope.

To return to the actual state of currents.—Those of the South-Atlantic afford a fairer specimen of the general effect of the trade-winds in producing *drift currents,* than those of the North-Atlantic; because the regularity of the latter is more disturbed, by adventitious causes; namely, by two broad streams of current, the N.W. branch of the equatorial, through its central parts, and the North-African and Guinea current, on the eastern side: and, moreover, by this ocean being less serene than the Southern-Atlantic.

It is not improbable that the reader may be led to expect a more regular and uniform course of the drift currents throughout the whole of the North-Atlantic, and part of the Southern, than what actually prevails there. But the fact is that, (as we have already stated,) the regular trade-wind blows from different points in different parts of the same Atlantic, at the same season: that is, more *along-shore* upon the shore on the side of the old continent,

and more towards the new continent on that side; varying all the way across by gradually becoming more and more easterly; forming a kind of *concentric* curves; and, that the drift currents obey these winds. So that, for instance, the water, impelled from the eastern and the middle parts of the South-Atlantic is carried into the Equatorial current; but that from the western part is carried to the coast of Brasil, and serves to increase the Brasil stream or current.

Here it may be proper to speak of the rate of motion of these currents: and first of the DRIFT CURRENT.

The Author examined a very great number of journals with this view; particularly in S.E. trade, which (as it has been observed) affords the best *data* for the drift currents; and particularly in the Indian Ocean: and, from examples, from what he deemed the best authorities, he concluded that about twelve miles per day, or half a mile per hour, might be taken for the effect of the trade-wind, (taken at a *mean*) in generating a motion of the surface of the sea to leeward.

The STREAM CURRENTS have different degrees of velocity, up to $4\frac{1}{2}$ miles *per* hour; which is the highest that appears, on good authority, in the open sea, and that in a very few instances only. In the outfall of the Gulf-stream there are two instances of 5 miles an hour, or 120 in the 24 hours, but they appear to be rather the effect of a fall from a higher level, than by accumulation. There are examples of 3 and $3\frac{1}{2}$ in the Equatorial current, but more

commonly $1\frac{1}{4}$ to $1\frac{1}{2}$: the North-Atlantic under one mile generally; and the Guinea from one to two. The Gulf-stream appears to preserve its force the longest; it running $1\frac{1}{4}$ to $1\frac{1}{2}$ after a course of more than 2700 geographic or nautic miles; (more than 3100 British) from the Sea or Gulf of Mexico.

It must be remarked that, in some places, the current consists of a *mixture* of *drift* and *stream:* for a stream, already formed, may pass through the region of the trade-wind, in a direction corresponding with that of its *drift* current; and receive an acceleration of motion from it accordingly. This is the case of the North-African current, which passes by *Madeira* and the *Canary Islands:* and which was, of course, formed, previous to its entering the region of the trade-wind. The same may be said of the Lagullas current, on entering the S.E. *drift* current of the Southern-Atlantic.

The most rapid and powerful streams of current, taken at large, are those occasioned by great volumes of water, in the nature of *drift*, forced by the trade-winds or monsoons into the *deep* and *capacious recesses* of the coasts, or of *basins*, fitted to receive and detain them, till collected in full force. For these waters, having acquired a more elevated level than the adjacent sea, escape by some lateral passage, that is, by the line of least resistance; and descending, form streams of current, of great magnitude and force; prolonging their courses through the surrounding medium,

to a vast distance. The *Gulf-stream of Florida*, at all times, and the *Equatorial stream* of the Atlantic, during the season of strong S.W. winds, are amongst the most remarkable of this class.

Hitherto, in order to simplify the subject, the *streams* of current have been considered generally, as *single streams* only; but the truth is, that some of them, in the midst of the ocean, either *divide*, or *send out branches*, that diverge very greatly from the course of the trunk stream: producing, in some cases, an effect equal to that produced by the principal ones.

It is well known that streams, of all kinds, have a natural tendency to *spread* as they recede from the place of their origin: but *these* are not *expansions*, but absolute separations, or derivations, from the *trunk* stream. Although apparently constant and regular, they have probably been the cause of some of the reported *changes* that have been said to have happened in the courses of currents, in the *same place*, or rather what was *supposed* to be the same place, through errors in the longitude: for it is to the more frequent use of chronometers, alone, that we are indebted, for the knowledge of the existence and nature of such derivations. The Equatorial stream (as we have seen,) detaches two of them, one to the N.W., the other to the S.W., and both of them continue their courses through the greater part of the regions of the trade-winds to which they respectively belong; and, it may be concluded that all principal streams send them forth, more or less: and that they have often

misled persons, who have attempted to form systems of currents too hastily. The causes of these separations remain to be accounted for; as also, why principal streams, in the open sea, should sometimes make inflexions in their courses like rivers: for this does really happen[1].

There are also, in certain parts of this ocean, (as every where else) sudden changes and *curvetings* of the current, for which no cause appears; so that, had not they been supported by many authorities, they might have been regarded as no more than errors from bad reckonings.

Counter Currents.—There are, also, attending some of the principal streams, Counter Currents: and these form an important point for consideration. They appear the most prominent when they emanate from streams that run beyond the limits of the trade-winds and their *drift* currents: as the Gulf-stream of Florida, to

[1] Two remarkable examples occur (within the Author's knowledge) in which currents *cross* each other: one passing *over* the other. One of these is the current or *outfall* of the river *Plata*, passing *over* the southerly current which proceeds along the coast of Brasil, as shown in *Chart* II. The Plata current ran at the rate of one mile per hour, and appears to be more than 300 miles wide beyond the distance of 600 geographic miles from the embouchure. The Brasil current re-appears, and continues as far as Staten Land.

The other example is the easterly current, along the south coast of Australia. In Bass's Strait it totally disappears; giving way to a regular tide: but re-appears in strength, at some distance beyond the Strait, to the eastward. In this case, both are *ocean* waters: but in the former, the uppermost had, of course, a large proportion of river water.

the northward of the parallel of 30°. For if a stream, within the trade-wind, runs *contrary* to the *drift* current, this latter will of course be a *counter current* to the other : and if *with* the *drift*, one merges in the other. Those from the Gulf-stream are the most remarkable for their extent and force; and, together with the main stream itself, require particular investigation, in the nature of a *survey* : as they so materially affect the course of the voyages between Europe and America[1].

Experience most fully proves, that, although nature effects all her operations in such a manner as that, ultimately, the whole system is balanced and preserved ; yet that, in detail, she often appears irregular, according to our limited comprehension. The trade-winds and the currents of the ocean partake of these irregularities, although the general system is upheld. The trade-winds in the North-Atlantic are often unsteady, as we have shown, even to 5 or 6 degrees, within their usual northern boundary; and, instead of N.E. winds, there are found N.W., and even S.W., winds, for many days consecutively : and this state of things

[1] It may possibly be owing to the counter currents of the Gulf-stream, that its warm water is spread out to *so vast a breadth.* In the ship in which Dr. Franklin returned to America, in 1785, they experienced a westerly set of about 300 miles, between the parallels of 33° and 37°; and, by *dead reckoning*, between the meridians of 45° and 70° west: having, at the same time, the temperature of the sea from 78° to 81° in August and September ; when the proper temperature of the sea, in these parallels, was from 72° to 74°. But, through the want of chronometers, the currents could not be ascertained, in detail.

13

prevents the *drift* current from being so regular there as in the heart of the trades [1].

Anomalies also take place in the great Equatorial current, and in that of the S.E. trade. The former has been known, at one time, to run to the eastward, or directly opposite to its general, and, as is commonly understood, perpetual, course; and at about the same rate; and with it, the whole mass of water, from 5° north to 12° south. At another time, a like anomaly took place, between the parallels of 2° north and 7° south. This latter was *observed to take place* at six or seven degrees to the eastward of Cape St. Roque; but the other, about midway between the two continents. In a third case, nearly in the middle, the current *ceased altogether:* or rather there was neither an easterly nor a westerly current. This happened in February; the other two, in July and August [2].

Sir James Yeo, in his voyage from Guinea to the West-Indies, along the south of the Equator, from the meridian of Greenwich to 15° west, and between the Equator and 1½° south latitude, found *no current*

[1] Those who sail to the West-Indies, &c. are less anxious about their *westing*, than their *southing*, until they have gained the heart of the N.E. trade-wind: for the reason just mentioned.

[2] Even in the centre of the Pacific Ocean, where, from the total absence of any large tracts of land, one might expect the trade-winds to be steady, Capt. Cook found in December (1777,) in the south-east trade, the wind so much to the north of east, that he could make no better course than to the *west* of *north*. And, having crossed the Equator to the N., he had some winds at east and south of east, but no regular N.E. trade till he came into about 8° north.

in August 1816; although four other persons have experienced from 22 to 63 miles *per* day, in the same month, and also in February and April. Accordingly, this is to be added to the list of *anomalies;* and, although it may be remarked that this gentleman's observations are very cursory and general, yet there can be no doubt of the general result in this place.

All these instances happened between the years 1796 and 1816.

All the known streams of current vary in their rate of velocity, at different times; and, in many cases, without any particular reference to seasons. The Gulf-stream is said to vary from $4\frac{1}{2}$ to $2\frac{1}{2}$ miles *per* hour, even in its passage through the Strait of Florida. The *breadth* of the *Equatorial* and *Guinea* currents, also, varies very greatly, in different seasons; and this may also be the case of other streams, of which the Author has less knowledge. These powerful streams, by their *expansion,* not only *brush* each other, as they pass in opposite directions, but often usurp each other's boundaries. That of Guinea, during the height of the S.W. *monsoon,* spreads very far to the south; and, at times, extends its course to some degrees south of the Equator, before it is opposed by, and finally *lost* in, the mass of water brought by the S.E. trade-wind; and which afterwards forms the incipient Equatorial current. And, on the other hand, in the like season, this latter is found more to the north of the Equator, after it has passed the meridian of Cape Palmas; for it is opposite to that

cape where the two currents press on each other more closely; and thereby visibly augment each other's velocity.

This may suffice to convince the reader that such currents often vary, in breadth and force: and perhaps, in some degree, in their lines of direction also. Nay, that one of the most considerable of them, (the Equatorial,) ceases altogether, at times, or changes its line of direction: *although one particular state of things is to be looked for, and will almost always be found.* It must be understood, that nothing is known concerning the great anomaly in August 1800, beyond the intervals of 9 and 10 days, respectively, that the ships were passing. It should not be omitted, that, in the example midway between the two continents, in August 1800, the current ran east at and to the north of the Equator; to the N.E. and northward of east from thence to 7° S.; and afterwards east, to 12° S.; and in the example nearer to Cape St. Roque it ran nearly due east. [*See Chart* I.]

When the whole of that great body of water between the two continents was in motion, towards the east, a very great change must, necessarily, have taken place, over the Atlantic generally: but the want of simultaneous observations at different places, must ever preclude a knowledge of the general state of the currents, at one and the same time; as well as of the cause of the change. It is difficult to conceive what could produce a total change in the comparative levels of the two

Atlantics: for such a change must have taken place, before the North-Atlantic could pour its waters into the South-Atlantic; directly contrary to the usual course. It happened at the season when the S.W. monsoon prevailed in the North-Atlantic, and in the Equatorial parts, and which might have had some share in forcing the water to the eastward. The *cessation* of current altogether happened at a season when the N.E. trade approaches to the Equator, and the S.E. is very much easterly; and less boisterous towards the coast of Guinea and the *Bight* of Benin.

The waste occasioned by evaporation in the Mediterranean, and in the supposed *recipient* of the water of the Gulf-stream, has been spoken of as one cause of producing currents in the North-Atlantic. It is well known that there exists, nearly in the centre of that ocean, a tract of more than 1200 geographic miles in length from north to south, in which the weed brought by the above stream, appears to be deposited in greater quantities than elsewhere; and it never varied its position, in any great degree, during forty-three years, or between 1776 and 1819. No satisfactory reason has yet been offered for its continuing stationary for so long a time, indeed for ages: for although 43 years are mentioned as the *known interval*, yet this refers solely to the observations since the date of chronometers; because its position could not have been *correctly* known till that time. But the truth is, that navigators, ever since the Atlantic has been crossed, in that direc-

tion, have found the weed, as nearly as their reckonings permitted them to judge, in the same general position.

The breadth of this mass of weeds is small in proportion to its length ; being drawn out, into a kind of *stream ;* and bending a *little* to the *east* of *south.* Dr. Franklin *crossed* it, in about latitude 36½°, and found it less than 50 miles in breadth, but it spreads as it goes southward, and in latitude 20° appears to have been, at times, 150 miles wide : although, perhaps, consisting only of various parallel *streams* of weed.

It is now known, that about 420 miles of this weedy tract (the northern part of it) lie in the warm water brought by the Gulf-stream ; so that one may well suspect the same of the whole, or the greater part ; and that this tract of weed really occupies, generally, what may be deemed the *recipient* of the water of the Gulf-stream of Florida. It is not yet known what the temperature of the Sargasso Sea, (so called from the weed deposited) southward of latitude 33°, may be ; but to the northward of that parallel, it is from 4½° to 5½° warmer than the natural temperature of the ocean : taking the *maximum* of *both* [1].

It has been already remarked (page 20), that it seems natural to conclude, that, as an increased evaporation must take place, throughout this tract, (as well as along the course of the Gulf-stream)

[1] More will be said concerning the Sargasso weed in the sequel.

that there must necessarily be a *depression of level* also, from the continual waste of the surface ; forming a kind of hollow space ; or, rather, depressed surface. It is certain that the setting of the currents is such, as might be expected to take place if such a hollow existed : for the currents do really set into the Sargasso Sea, from the north and from the south; whilst in the middle part, although within the region of the trade-wind, the currents are not regular, but rather indicate a kind of *vortex* [1].

If there really be a depression, it would seem to account for the existence of the north-west branch of the Equatorial current, which runs into it.

It has been very justly suspected, that the tract of warmer water, caused by the Gulf-stream, by its effect on the superincumbent atmosphere, occasions those frequent storms that happen near its line of course, across the Atlantic. The opinion certainly seems to be borne out, by a reference to the positions in which the storms were encountered, and in many cases so fearfully and fatally. (*These will be found in the Charts of the Currents.*) It proves also, the correct judgment of our forefathers, who, without any accurate knowledge of the *extent* of the Gulf-stream, but on their general experience, (which was perhaps of greater

[1] The early Portuguese navigators gave this part of the ocean the name of *Sargaçao* or *Sargasso,* from the form of the seed-pods, or fruit of the plant, which have been called *tropical grapes.* See, upon this subject, a paper in that useful and elegant periodical, the *Nautical Magazine,* 1832, page 175.—Ed.

value) established a maxim, that "the proper course from the West-Indies to Europe, in order to avoid the frequent north-west gales, lay to the south of latitude 34°." How this could have been forgot, is wonderful! or, did our successes render us presumptuous[1]?

Local Currents.— There are few coasts that are without their local currents, owing to the prevalence of particular winds, which impel the water along them, in a contrary direction; but these, being generally blended with the ordinary tides, merge so completely into them, that seamen and pilots themselves (as is perfectly natural) are in

[1] It is well known, that currents carry with them to incredible distances, a great portion of the temperature of the sea from whence they have their origin; even after flowing through 29 to 30 degrees' difference of latitude. Thus the Gulf-stream has warmed a large portion of the Bay of Biscay, in November and January. The southerly current, which runs from our parallels to Guinea, has been found when in latitude $22\frac{1}{2}$°, late in May, of the ocean temperature of 40° at maximum. The Equatorial current has been found $2\frac{1}{2}$° to $3\frac{1}{2}$° cooler in July, than the water on each side of it; being formed of water, brought by the S.E. trade-wind: and the Lagullas current, from the Indian Ocean, round the Cape of Good Hope, is at times 10 or 11 degrees warmer than the natural temperature of the sea at that place.

It appears therefore, that, by attention to the *thermometer*, much information may be gained, and dangers avoided.

It indicates the approach to land, as is shown in two remarkable instances, by Dr. Davy, in his excellent paper on this subject in the Philosophical Transactions. But, in the case of *ice*, its use is most striking: for the temperature of the sea has been affected long before the ice was visible from the mast-head. Two remarkable instances of this are given in the Current Chart, No. II.

southerly current from our parallels, towards the Equator; and that which, from the side of Brasil, partly joins the Lagullas current, in its way up the south-east trade; and partly forms an easterly current into the Indian Ocean.

GENERAL REMARKS.

The reader, conversant with these subjects, will be aware that there could be no other mode of accomplishing the work before him, than by comparing the intervals in the ship's reckoning (commonly called the *dead reckoning*), with the celestial observations taken from time to time; the differences between which are usually taken for the effect of currents. But it is obvious, that a *part* of these differences *may*, and no doubt *does*, commonly arise from various causes of error, to which a reckoning is subject; such as *bad steerage*, *imperfect compasses*, *faulty admeasurement* of distance, and erroneous judgment, in making allowances for leeway and drift; and, finally, in the calculation of the *traverse*. To each and all of these errors, a reckoning is, doubtless, subject, and some one or more of them, may be continually operating. The question then seems to be, "how near an approximation to the truth may be made, by the means of ordinary judgment and care, and in ordinary weather?"

Captain Flinders, whose ability in practical, as well as theoretical, navigation, stood very high, and who attended, more than most men, to experi-

ments of this kind, has given it as his opinion, that, under favourable circumstances, a reckoning might be kept within five miles of the truth, in point of distance, and in bearing, to half a point.

It will be found, on calculation, that the amount of these supposed errors, first taken *separately*, and afterwards combined in all their varieties, gives eight different results, as the differences between the dead reckoning and celestial observation, for a particular day; allowing a ship to have sailed 120 miles, on a N.E. course. The differences are from 5 to 13 miles, on different quarters of the compass; and indeed, almost all round it. However, most of them are to be taken as extreme cases[1].

Here then is an admitted possibility of error, of such a kind and magnitude as would render all results from reckonings nugatory, as they respected the detection of currents, were such errors to happen ordinarily. That such errors *do* happen, is well known; but let it be inquired, "what is practically the fact, as it regards the great mass of information?"

[1] The error, or difference, of miles in *excess* would appear as a current of N.E. 5 miles.

———— of 5 miles *short*, S.W. 5.

On half a point in bearing, N.E. 12; or S.E. 12.

On the same error in bearing with 5 miles distance in excess, E.S.E. 13; or W.N.W. 13.

On the same error in bearing, with 5 miles distance short, N.N.W. 13; or S.S.E. 13.

It must be in the recollection of naval officers, that oftentimes the day's work has given a very different result, from what they anticipated, when the current had been tried.

If then we cast an eye over the Chart of Currents, it will be seen that in the four great streams of current, the best known in the Atlantic, that is, the *Gulf-stream*, the *North-African* and *Guinea Current*, the *Equatorial Current*, and the *Lagullas Current;* the examples in each stream, respectively, point generally the same way [1]. The journals themselves, were, indeed, selected; but it was on the score of their acknowledged authority, and not for their giving support to any particular system: nor was there any selection of particular examples, in order to prove particular facts; but the whole matter of the subject was taken together, as it stood: for it was the system of the Author, to introduce *every example* that occurred, in the journals that were consulted; in order that the evidence, *on both sides*, might appear: and afterwards to draw his own conclusions, either from the *quantity* or *weight* of the evidence; especial regard being had to the latter. And the result of his judgment is expressed, in the charts, by a sort of

[1] This circumstance speaks forcibly in favour of the journals of those classes of ships, which are most in the habit of using these navigations, and which carry chronometers, &c.: that is, his Majesty's and the East India Company's. Had they been *ill kept*, the same variations in the setting of the currents would appear in the *great streams* of current, as in the other parts of the ocean.

No other class of journals has been made use of, in this work, for the currents, but those of his Majesty's ships, those of the East India Company, and of foreign ships equipped for discovery, with the trifling exceptions of a Government packet, and of those of a scientific commander of Glasgow, latterly of Liverpool.

larger and stronger darts than those in which the examples are expressed. This will put the reader at once in possession of the Author's opinion, as well as of the means of enabling him to exercise his own. To discriminate the different degrees of value of the evidence, would be impracticable; but marks are placed on the examples, by which an idea of superior authority is meant to be conveyed.

There can scarcely be a doubt, that, from the presence of some of the above errors, the currents are oftentimes reported to be of greater or lesser strength than they really are; and with degrees of obliquity, different from the truth. But this does not vitiate the general result: any more than a contrary evidence on a trial, where the great mass of evidence points to the establishment of a fact. And it would appear that the journals may be regarded as *a series of reports*, which, taken at large, are by no means discordant amongst themselves; and from whence useful practical results may be drawn. Approximation, alone, can be hoped for or attained, in this as well as in many other practical cases.

It would have been too hazardous a measure, to regard any principal fact as being established on the authority of a *few* examples only; unless they were the observations of persons of known judgment and accuracy.

Every good has its concomitant evil. It is to be feared that the facility of finding the longitude, by means of chronometers and lunar observations,

may occasion less attention to the ship's reckonings, than is consistent with safety; on the ground that *the next day's observation will set all right.* This is greatly to be deplored: as, in many situations, it would place the ship in a state of less safety than before the improvements took place. Suppose an interval of one, two, or more, days, to pass, without observations, (as occasionally happens) and under the expectation of making the land, with a reckoning not to be depended on, during the interval since the last observation! The least evil would be that such a system would *put an end to all improvements of current charts:* and it must be recollected, that they are, at present, in their very infancy[1].

[1] It appears extraordinary that the *patent log*, to my view so admirably calculated for measuring the ship's way correctly, should be so little in use: particularly when recommended by some of the most distinguished naval officers.

Captain Parry, of his Majesty's ship Alexander, on his first voyage to Baffin's Bay, tried a patent log against a common log, on a run of 1746 miles. The result was, that the common log gave 1764; or as nearly as possible, *one hundredth part more* than the patent one. Had this been the only difference, it might rather help to confirm the use of the common log: but some of the intervals differed as much as a *ninth*, a *seventh*, and even a *fifth*, part. These great differences arose on the *very short* runs; the patent giving the greatest distance of the two; whilst, on the other hand, the old log gave, almost uniformly, the greatest distance of the two, on the *long runs:* but the proportional distances approached nearer to the truth.

One may conclude from the circumstance of the greatest differences happening on the short runs, that it arose from the difficulty of apportioning the hourly distance, under frequent

With regard to the reckonings of ships, generally, a practice has always prevailed of bringing the course, or distance, or both, by the reckoning, to square with the observations of latitude. But as the difference so often proceeds from currents, which may set either way, it would be better not to meddle with the course; but to keep the longitude according to the reckoning. There is no doubt but that reckonings are often made worse by this attempt at correction; and, in ships that make use of chronometers and lunar observations, the currents will not be so accurately shown as if the reckoning was left in its original state: that is, after making the proper allowances for *leeway, drift, and variation.*

Some recent experiments having been made with a view to ascertain the direction and force of certain currents in the North-Atlantic Ocean, it may be proper to give the results of several examples that have come to the knowledge of the Author, by the kindness and assiduity of his friends; as they have a bearing on the general subject.

There are many circumstances in proof, either of a motion of the sea from west to east, or of a regular *drift* by the mere action of the reigning

changes of the rate of sailing, in light and baffling winds; whilst the patent log required no exercise of the judgment.

This circumstance, then, seems to show the great value of the new instrument, in narrow seas, or in approaching the land, when unsteady winds prevail: and more particularly in the night.

winds, or both, across the whole breadth of the Atlantic, from *Nova-Scotia*, *Newfoundland*, &c. to the shores of Europe; and, generally, to the northward of the Gulf-stream; whose boundary may be taken at about the parallel of 44° in the middle of the Atlantic.

In the first place, the universal testimony of navigators, between our islands and the northern parts of America, that they measure much less distance on the passage *homeward* than *outward*. Some calculate the difference roundly, at one-tenth: but by this, is probably meant, *the difference between the two accounts, out and home,* which, of course, would give a difference of one-twentieth less than the actual distance on the globe [1].

Experiments have indeed been made, from time to time, during the course of the last twenty years, to try the direction and rate of currents in the North-Atlantic, by throwing bottles into the sea, containing papers, noting the time and place when they were thrown out. Many of these have been picked up, on the coasts of Europe, and on the West-India Islands: and, on the whole, much *general* information has been obtained. Articles

[1] The voyagers from the west of England to Newfoundland reckon the distance about 2100 miles between the western ports and St. John's, but 2000 is nearer the truth. Now if they are retarded on the outward passage, so as to reckon 2100, and receive a help, on the return, so as to make only 1900, they may possibly call the help 200 miles, which would be equal to one-tenth: but is really no more than one twentieth, on the actual distance.

from wrecks have also appeared, whose dates and places of departure have been known.

It may be useful to mention, in this place, that the bottles, &c. from the northward of the parallel of 44° generally, were carried to some part of the coast of Europe; that is, their line of direction was east, or north-eastward: but that all to the south of that parallel, were carried to different parts of the West Indies, or to Bermudas; as, one to *Bermudas*, one to *Martinique*, one to *Inagua*, and three to the *Bahama* Islands; namely, *St. Salvador*, *Eleuthera*, and *Crooked Island*: proving the prevalence of an *easterly* or *north-easterly* current, on the *north* of the Gulf-stream, and of a *S.W.* or *westerly* one, on the *south* of it[1].

But, it is obvious that such experiments can never determine the *courses* or rates of the currents, to which these floating substances have been subject; especially if the interval has been long; since various, and even *contrary*, currents may have acted on them. But even the *winds* will derange such experiments; for it is possible that *they* may have had, on the whole, more effect on the float than the current which they were intended to detect.

Even a ship, with a tolerably correct reckoning, and with celestial observations, will afford a better experiment; since her lines of direction, on the several courses, although not *accurately defined*,

[1] Several other examples are given in the Appendix hereafter.

are at least, approximated. But the *floats* only show their route, reduced to *one general line;* the intermediate deviations being utterly unknown: and accordingly, nothing is gained but a knowledge of the effect produced by the *combination* of *winds* and *currents;* but without the *proportion* of each: and, when they have been at large, during many months, or even great part of a year, (one was taken up *five* years after it was thrown out,) they may have traversed the ocean more than once. They can be truly useful only when taken up in an early stage of their progress. However, in the absence of all other information, they may be received as presumptive evidence.

The examples collected by the Author[1] are many, in different parts of the North-Atlantic;

[1] NORTH OF THE GULF-STREAM.

NAMES OF SHIPS.	FROM WHENCE.			PLACE OF ARRIVAL.		INTERVAL IN DAYS.	RATE OF COMING.
	Lat.	Lon.	Date.	Place.	Date.	Days.	Miles.
	N. °	W. °					
Iris, Capt. Skinner	47	21	Sept. 9, 1802	I. of Skie	Feb. 22, 1803	165 N.E.½N.	4·9
No name {From Capt. Hurd}	52	27½	June 25, 1806	Urris Head, Ireland.	Early in October, 1806.	105 E. 14° N.	5·75
Little Belt's bowsprit (*see Append.*)	Halifax	—	Aug. 1809	Basque Road	Feb. 18, 1811	547 E.	4·8
Seine	50¾	40⅓	Sept. 18, 1811	Co. Kerry	June 18, 1812	270 E. ½ N.	4·11
London, wreck ..	61½	57	April, 1817	Orkneys	Mar. 20, 1818	Abt. 320 E.S.	4·9
Alexander	58	44	May 24, 1818	Killala	Mar. 17, 1819	297 E. 11° S.	3·94
No name........	49	43	———	C. Finisterre	May, 1818	E. 14° S.	—
The two highest 5¾						Mean of all	4·73
The two lowest 4						Mean of highest and lowest	4·84

but in the quarter northward of 44° latitude, there are only seven whose rates can be made out. These consist of two pieces of wrecks, and five bottles thrown out experimentally, from different quarters; that is, the wrecks from Halifax, in Nova Scotia, and from Davis's Strait; and the bottles from Cape Farewell (off Greenland), and from different parts of the ocean, from $47\frac{1}{2}$° to 58° latitude; and from as far west, as 43° of longitude, to a point only 200 leagues to the S.W. of Cape Clear. These have been *thrown up* on different parts of the coasts of Europe, between Cape *Finisterre* and the *Orkneys*, inclusive. The mast of a wreck is also known to have been brought from the West-Indies to the *Hebrides* of Scotland, during the seven years' war.

But the tracks of these several *floats*, between the several points of their *departure* and *arrival*,

SOUTH OF THE GULF-STREAM.

NAMES OF SHIPS.	FROM WHENCE.			PLACE OF ARRIVAL.		INTERVAL.	No rate of course can be obtained; but merely the final result of the drift in bearing.
	Lat.	Lon	Date.	Place.	Date.		
	N. °	W. °					
No name {From Capt. Hurd}	$33\frac{3}{4}$	$64\frac{1}{2}$	May 28,1802	St. Salvador	Dec. 18,1802	6 months	
No name {Capt. Hurd}	$44\frac{3}{4}$	45	June 6, 1802	{Near Bermudas}	Dec. 2, 1804	$2\frac{1}{2}$ years	
No name	38	$53\frac{1}{4}$	June 4, 1806	Crooked I.	Nov. 18,1809	$2\frac{1}{2}$ years.	
Elizabeth Packet	$14\frac{1}{2}$	25	Sept. 1808.	Martinique	———	224 days.	
William Manning	35	$14\frac{1}{2}$	Sept. 9, 1810	Inagua	Oct. 19, 1815	5 years	
No name	22	$27\frac{1}{2}$	Aug. 8, 1816	Eleuthera	Mar. 4, 1818	18 months	

differ widely; so that not any two of them, thrown out separately, made the same course. But, on the other hand, all whose dates of departure and arrival are known, came nearly at *the same rate of motion* as if they had been subject to the same degree of impulse, but exerted in different directions: the two highest rates being $5\frac{3}{4}$ miles *per* day; and the two lowest, 4·11, and 3·94, (or say 4 each,) whilst the three others were respectively 4·8, and 4·9. Accordingly, the mean of *all* was 4·73, and of the *highest* and *lowest*, 4·84. And here it is remarkable, that the rate of the wreck from *Halifax* to *Basque* Road, was in effect the same as that of the bottle from 200 leagues S.W. of *Cape Clear* to the Island of *Skie;* although the former was carried *eastward,* 870 leagues, and the latter on a N.E. $\frac{1}{2}$ N. course, 200 only!

It appears then, from the note, page 84, that one bottle from about lat. 58°. and S.E. from *Cape Farewell;* and others from the different parallels of 51° and 52°, all reached the western coast of Ireland, between *Killala* Bay and *Dunmore Head;* but on various courses: that is, from E. by S. to E. 14° N.: that another, from lat. $47\frac{1}{2}^{\circ}$, and S.W. from Cape Clear, reached the Island of *Skie*, on a N.E. $\frac{1}{2}$ N. course: that a wreck from *Davis's Strait*, in lat. $61\frac{1}{2}^{\circ}$ long. 57° W., came to the *Orkney* Islands, on a course of East, *a little southerly:* that another from lat. 49°, long. 43°. came a little to the southward of *Cape*

Finisterre (3 leagues) on an E. 14° S.[1] course; (whilst one of the before-mentioned, from a point only 150 miles or less, from the former, was carried to *Ireland*, on an E.½N. course). And finally, that the wreck from *Halifax* came all the way across the Atlantic, on nearly an east course. When this is considered, it must strike every one, that, whatsoever currents *may* exist in this quarter of the Atlantic, they cannot be supposed to be at once so *various* in their *direction*, and so *regular* in their *rate of motion*, as to produce the just mentioned effects.

The *shortening* of the *distance* on the return from America, according to general testimony, ought to be the effect of currents *alone;* since what would be accounted mere *wind-drift*, in respect of the bottle, is, in this case, included in the measure of the ship's *way*. Therefore, as the above testimony goes to an *acknowledged fact*, it so far proves a general motion of this part of the *ocean* to the *eastward;* or rather, perhaps, the *balance* of *easterly current;* as the intermission of westerly winds must necessarily suspend the easterly current, and, in long intervals, change its direction; as is proved by a multitude of examples in journals. And even the effect of the westerly winds, during the intervals when they blow, cannot be in equal proportions to that of the trade-winds in producing *a*

[1] Another bottle thrown out, at about 80 leagues W. 13° N. from Cape Finisterre, or precisely in the same line of direction with the former, came also to the same spot; but after a very long interval.

drift current; since the impulse in *these* is *unremitted*, but in the other requires to be gradually *renewed* with each change of wind.

The slow rate of motion of this current, or drift, as shown by the *floats*, may possibly occasion surprise. It must, however, be considered, that 4·9, (or say 5) miles *per* day, is nothing more than the *balance* of easterly drift; when allowance has been made for the effect of *all the winds from the eastern side of the meridian*. On a rough calculation, there appears to be a proportion of nine days of westerly winds to $5\frac{1}{4}$ of easterly: and, on this proportion, the effect of wind, to produce a *drift* current, would be about 8 miles per day, or one-third of a mile per hour[1]. The *settled* trade-winds doubtless produce considerably more, but a reason for it has been offered above, where 12 miles *per* day has been taken as the mean rate of *drift* currents.

And here, to prevent any erroneous conclusions from being drawn from an *apparently similar* case, it may be proper to mention that, the rate of mo-

[1] This proportion was formed, on the authority of Journals of the Weather, in different parts of *Great Britain*; but most commonly in *South Britain*. It differs but little from the result of a journal kept by Lieut. Mackie, in the British Islands, between A.D. 1802 and 1816, (14 years). He reckoned 216 days of westerly, and 135 of easterly, on a mean of the whole: giving a proportion of 72 to 45; or 9 to 5·62; whilst mine is 9 to $5\frac{1}{4}$. In months 7·515, to 4·435, or say $7\frac{1}{2}$ to $4\frac{1}{2}$. (See Blackwood's Edin. Mag. for October, 1818.) His result, of course, ought to supersede mine. And, although the state of the winds at one extremity of the Atlantic may not apply strictly to the whole of it, yet it is the only approximation that the Author could obtain.

tion of the current, in the region of westerly winds in the South-Atlantic, and which far exceeds that in the North, furnishes no rule by which we can draw any conclusion respecting the rate of this latter; because the easterly current, in the south, is more a *stream* current, formed by the accumulation of water impelled to the westward, by the south-east trade-wind; and which naturally escapes by the south and east. But the waters accumulated by the N.E. trade-wind, being those which form the *Gulf-stream*, cannot be supposed to have any share in forming a current in that portion of the Atlantic under consideration; since they pass to the southward of it; so that it must be supposed to derive *its* current from the effect of the westerly winds alone. And, on the whole, one cannot but conclude that, beyond the limit of the Gulf-stream, northward, throughout the Atlantic, a general easterly *drift*, or current, prevails; but is very *slow* in its rate of motion; and that the variety of directions taken by the several floating substances, obliquely to the N. and S. of east, are to be referred to the effects of the various winds, which operate on those floats; and which, although they *determine absolutely* the courses of the *floats*, yet can act on a *ship* only in a *combined ratio* of the current which they have set in motion, with her proper course by her reckoning. It may be remarked that a great proportion of the floats are carried to the *northward* of *east;* and S.W. winds are known to happen more frequently than any others.

It remains to be stated that the bottle thrown out by Capt. Parry, near Cape Farewell, and the wreck from Davis's Strait, were evidently subjected to the stream or streams of current, from the east side of Greenland, and from the west side of Davis's Strait; and that they would be carried to the S. or S.W., by them, so long as the wind did not operate on them *laterally*, to blow them out of the stream; which, of course, would depend on the direction and force of the winds. As those from the westward are the most prevalent, the floats would, in no long time, be blown into the Atlantic, at large; and would then drift to the eastward, with the general wind and current.

Not long after leaving the bottle, Capt. Parry, being then arrived within Davis's Strait, came to a vast Island of Ice, (the first seen in the voyage,) which must also, from its position, have been in the same current. At first it might appear strange that, as the bottle came to Ireland, and the wreck to the Orkneys, no ice should come; at least a part of that way. But this may obviously be accounted for, by the amazing difference between the nature of the two bodies. The ice, subtending a column of water, of several hundred feet in depth, and with a small proportion of its bulk above water, yields but little to the wind; whilst the bottle skims the surface: and as the course of the general wind is almost at right angles to that of the current, it is very improbable that they should keep long together.

The general course of the ice brought from

Greenland, Hudson's Bay, and Davis's Strait, is regulated by this current: or it may be, by *two* currents; one from Davis's Strait and Hudson's Bay, the other from the Polar Sea, along the eastern coast of Greenland; and which may probably fall into each other, at the S.E. part of the great Bank of Newfoundland. For it appears to the Author, both from *his own* and other people's observation, that two distinct *streams of ice* exist; one on the east of the Bank, the other ranging along the coasts of Labrador and Newfoundland; and thence obliquely across the Bank in a S. by E. direction; whilst that from Greenland, &c. runs between the S. by W. and S.S.W. This southerly current appears to fall into the Gulf-stream, about the latitude of 43° or 44°; and between the meridians of 45° and 50° W. The ice is, of course, carried into the Gulf-stream, where, from the warmth of its temperature [1], it must rapidly dissolve. Many very large Ice Islands have been seen so low as 40¾° latitude, and 46° of longitude; but were then in a state of rapid decay. The Author has heard of none, from authority, that have been seen to the eastward of 46° west; but of many to the westward, in the line of the route from Halifax. These may possibly have come through the Strait of *Belle Isle*, as they are often seen *in it*, brought by a branch of the Davis's Strait current [2].

[1] The maximum was 76° to 79°, about this place; and that of the ocean itself 68° to 69° in August.

[2] The following note contains nearly the present state of our

ICED WATER.—There yet remains to be spoken of an effect occasionally produced on the temperature of a portion of the Gulf-stream, (as well as of the ocean at large,) by the presence of islands of *ice:* and the means which may be employed to derive greater security from accidents in approaching them, in the night, or in thick fogs.

This was exemplified, in a remarkable manner, on board the *Eliza* packet, in her passage from Halifax towards Europe, in 1810: an attention to which may prove of use to all ships navigating

information, respecting the currents from Greenland, &c. into the Atlantic. [1820.]

That the stream down the eastern coast of Old Greenland, appears to send off a branch to the S.W. which passes Cape Farewell, and runs up the west coast of Greenland, carrying with it much ice. That no current seems to have been observed in *Baffin's Bay;* but that, to the south of Cape Walsingham, (in lat. 66°,) a current of 8 or 9 miles per day, to the southward was observed; and which increased to 15 and 16, as they opened the mouth of Cumberland Strait, and that of Hudson; but nothing farther is known southward. The same southerly current was felt, in a slight degree, across the mouth of Davis's Strait, in October.

Unless some *unknown* opening gave rise to the current at Cape Walsingham, one can only suppose that the current off Cape Farewell crosses the Strait (Davis's) obliquely, and is turned to the southward, by the form of the land, at Cape Walsingham. The report of the whalers, is in favour of this supposition. This appears to be the same stream, joined with that from Hudson's Bay, which brings the ice southward, along the coasts of Labrador and Newfoundland; and probably joins the Greenland current, afterwards. It appears clearly to the Author, both from his own observation and that of others, that there are *two distinct streams* of ice; one *within*, the other *without*, the great Bank: and he concludes that these have each a distinct current.

such parts of the ocean, as are at any time incommoded with ice. The particulars are amply detailed on Chart II., and the following observations will explain them more fully.

This ship, late in April, crossed the *Sable Island Banks*, with an ocean-temperature of 40° to 41°, and then came into 62° and 64°, in latitude 42° 15′; longitude about 60° west. Here they considered themselves to be entered within the verge of the Gulf-stream, though beyond the limit assigned to it by Dr. Franklin. The temperature of 64° is certainly about 4° above the ocean-temperature at that season; but which was probably not the stream itself, but its overflow.

From thence, in a general easterly course, 34 leagues, with a temperature of 60° to 62°, and still within the supposed limit of the Gulf-stream, the water suddenly fell to 58°, and afterwards gradually to 45°, in the distance of 11½ leagues. They now discovered the cause to be a number of *Ice Islands*, which they passed at the distance of seven miles, in 45° to 46° of temperature. The group extended about five leagues west to east.

Passing on, the water rose again to 50°, and afterward to 60°: but the 50° was much farther distant from the ice than the 58° in coming towards it. In effect, a space of 36 miles in extent in advancing to, and 57 after leaving, the ice, was cooled from 10 to 16 degrees below the temperature of the surrounding sea; for, at seven miles from the ice the temperature was lowered to 45°, or 16° below the general temperature of the sea.

After recovering the temperature of 60° (on still going eastward) they came to a second group of Ice Islands, at the distance of sixty leagues from the former, the intermediate temperatures being generally 60° to 62°; but also, at times, 63° to 64°. The extent of the space cooled here was much the same as in the former case, with this difference, that the extent of cooled water, in each case, was nearly equal in advancing and retiring, and that the temperatures were *lower* as passing nearer to the ice. This line of course, (according to the charts) should have passed over the very edge of the termination of the great Newfoundland Bank: if it were really so, that might also contribute to lower the temperature. This was generally from 43° to 44°, but once, close to a lofty iceberg, only 39°, while the atmosphere had 33 degrees.

From hence the temperature rose again to 60°, which continued generally to about 115 leagues, on an E. by N. course, to longitude $41\frac{2}{3}$° W. in latitude 43°, and very near to a situation in which Captain Beaufort, in August of the preceding year, had 73° to 74° of temperature, or 6° above the temperature of the ocean-water, in that place. But the *Eliza* had generally 60°, the ocean-temperature at that season, (beginning of May,) although she had passed through sixty leagues of the space, very near to which Captain Beaufort, in the preceding summer, had 73° to 76°: and, indeed, the whole of the *Eliza's* run, from longitude 60°, was through water scarcely above *natural* temperature, although the whole had been, from thermometrical

observations, considered as within the Gulf-stream: and it is certain that part of the tract in which there was *Gulf-water*, when Captain Beaufort passed eight months before, was now filled with water of the ocean-temperature. Is it then that ice had cooled the water in all that line, since it is found that a few Ice Islands may render cool a circle more than ninety miles diameter? This is a quarter in which much ice is found in spring and summer; some drifting through the Strait of Belle Isle, whilst a much greater quantity is brought by the southerly current that ranges along the eastern coast of Newfoundland. Many large Icebergs have been seen $40\frac{3}{4}°$ at Midsummer, but in a state of great decay; having been, of course, a long time subjected to the warmth of the Gulf-water.

But however *curious* this question may be, it is yet far more *useful;* since it proves that, by an attention to the thermometer, especially in the night, or in foggy weather, the presence of ice may be ascertained, and preparations made accordingly.

CHAPTER II.

ENLARGED DESCRIPTIONS AND DETAILS OF THE SEVERAL CURRENTS.

1. The LAGULLAS BANK and CURRENT, &c.

[Chart. III.]

(*December*, 1820.)

The two streams of current from the Indian Ocean, the one from the Channel of Mozambique, down the S.E. coast of Africa, the other from the ocean at large, (both the drift-water south-westward,) join nearly opposite to Point Padron [1], and probably near the edge of the bank, which in that part may not extend above forty miles from the above shore.

Of the two streams, that from the north or Mozambique Channel is by much the strongest. Its direction taking it up at the first point of Natal, in latitude 32° 20′, is about S.W. ½ S., [S. 40° W.] bearing somewhat off shore, in its course towards Point Padron and Cape Recife, occasioned probably by the coast of Natal, which has a direction

[1] The longitude of Point Padron is 26° 20′ E. that of Cape Recife, 25° 36′.

somewhat more north and south, and which direction it has previously acquired.

This line of direction adds, of course, to the safety of the navigator when ships make their landfall at the land of Natal, as the Doddington Rock and its neighbouring islets are very dangerous.

The *Eastern Stream*, from the Indian Ocean at large, (and formed of the drift water impelled by the S.E. trade-wind to the N.W. where the eastern shore of Madagascar first arrests it,) and running off, proceeds with a course between W. by S. and W.S.W. [W. 15° S.] and is traceable all the way from longitude 55° E., in latitude 25° S. In approaching the coast of Africa, the journals I have examined extend its southern border to about latitude 35° in longitude 55° E. (Ten degrees wide of Madagascar, to the S.E.)

When the two streams are connected, between the *First Point of Natal* and *Cape Recife*, they form a stream of 90 to 100 miles in breadth, which acquires a moderate velocity on the side towards the bank (denominated from Lagullas), and commencing about the First Point of Natal, or meridian of 29° E.; it being found, in two instances, $4\frac{1}{4}$ and $4\frac{1}{2}$ miles per hour; in many instances $3\frac{1}{2}$ and 3, to $2\frac{1}{2}$ very commonly. The rate of $3\frac{1}{2}$ has been experienced as far west as longitude 24°.

After the collective stream has reached the meridian of Cape Recife, (which is upwards of sixty leagues from the first Point of Natal,) it gradually turns to the west; its main body continuing to

the border of the bank, which trends in a direction of W. 16° S., or say W. by S. $\frac{1}{2}$ S., 50 leagues, to the bay or *rentrant* angle in the bank, where it suddenly turns to the [S. 20$\frac{1}{2}$° W.] S.S.W. The main body or central part of the stream appears to strike on the bank on, or about, a W. by S. course, in about 35$\frac{1}{2}$° of latitude, and longitude nearly 23°, by which it is immediately deflected southward to S.W. by W. [W. 36° S.] and by the time it arrives at latitude 36° to S.W. Still gradually declining, as it proceeds southward, it becomes S.S.W. before it reaches latitude 37°; in 37$\frac{1}{2}$° due south, and in 38°, rather to the east of south, where, for the present moment, we will leave it.

Pursuing the Great Lagullas Stream to the southward and eastward;—the observations of the current and temperature made in two years, 1819, 1820, by the Captains Hamilton, Alsager, and Wilson, have given some new ideas relative to the course of this stream.

It was formerly thought, by most persons, that the entire body of the Lagullas stream passed round or over the bank to the westward, into the Southern Atlantic; but it now appears evident that the *greater part returns back into the Indian Ocean*, towards the opposite quarter from whence it came; merging into the well known easterly current that issues from the South-Atlantic, and passes to the southward of the Bank of Lagullas and string of the Lagullas current, in its way round the bank from the Indian Ocean; both occasioning great eddies and irregularities near their respective

borders. The Atlantic current preserves its general easterly course to at least one hundred leagues east of the bank, and thence mixes with the oceanic waters.

The northern border of this easterly stream, (which appears to have a breadth of sixty leagues, between the parallels of 37° and 40° at its issue from the South-Atlantic,) passes by the (supposed) termination of the bank, between the parallels of 38° and 39°, in longitude 21° nearly; and, as Captain Cook appears to have entered it, in his way northward, nearly in the parallel of 41°, longitude 24°, it cannot have a less breadth than 120 to 130 miles in that part[1].

In order to its passing round the bank, and at times to leave a space for the passage of the portion of the Indian or Lagullas current, which passes between it and the south point of the bank, the *Counter-current* is necessitated to take an E.S.E. course from the Atlantic. Having passed the meridian of the south part of the bank, it appears to receive into it, in the first instance, that part of the Lagullas stream which passes to the south, along and over the eastern border of the bank, and soon afterwards to be joined by the *main stream* itself, which now takes a general easterly course, parallel to that of the other, and with which it mixes its waters; the two thus forming a collective stream of current, whose northern border is found in 36½° in the longitude of Point Padron, and at the same

[1] See Captain Cook's station on Chart III.

time as far south as 40^{0} or 41^{0}, being $3\frac{1}{2}^{0}$ or 4^{0} of latitude, or 210 to 240 miles in breadth.

It would appear, then, that the largest portion of the Lagullas or Indian Ocean current traces back a course nearly parallel with, and almost directly opposite to, that on which it came forward, and at no great distance from it, and may be reckoned as the central part of the stream, or as that which passes across the bank, the western part, for the first 110 leagues. It is traced on its general easterly course to the longitude of 60^{0} east[1], where it appears to take, generally, a more northerly course; throughout, the two currents appear by the run to be united, and they exhibit a general easterly current between the parallels of $35\frac{1}{2}^{0}$ and 36^{0} and 40^{0}, with a gradual diminution of force and of temperature, the correspondence between which is remarkable!

TEMPERATURES OF THE SEA.—Hitherto the temperature of the water of these currents, so far as they have been observed, has been only *alluded* to, but will be found, in the detail, to illustrate the courses of the different streams very satisfactorily; and, indeed, to afford a powerful aid towards their detection.

Taking up the Mozambique stream at the end of June, between latitudes 32^{0} and 33^{0}, and about thirty leagues to the eastward of the First Point of Natal, Captain Hamilton found the temperature 70^{0}, or about $8\frac{1}{2}^{0}$ above ocean temperature. Thence

[1] See Chart the fourth.

ranging the coast, near the edge of the bank off Cape Recife, he found 68°, or 8° above ocean temperature. Arriving nearly on the meridian of the Round Mountain, or $24\frac{1}{2}$° E. and to the southward of 35°, he had 67°, or 7° above ocean temperature. After this he was driven to the north and N.W. on the bank, between the last-mentioned meridian and Cape Vaches, and was once far to the north. His temperatures varied on the bank from 5° to 6° above, down to ocean temperature itself; he being then chiefly in the eddy easterly current, where the W.S.W. current has had time to cool, as above-mentioned.

Near the edge of the bank, where it trends to the S.W., and in latitude $35\frac{1}{2}$°, Captain Hamilton also had 67°, or 7° above ocean temperature; and he had the same on the bank twice, in a direction of about W.S.W., south from the last position; that is, 7° above ocean temperature: so that he found this temperature at more than forty miles within the edge of the bank, in latitude 35° 45′, and to this point also, and beyond it westward, he experienced a S.W. current of 49 miles, or two miles per hour; of course *flowing over the bank*, which arm of current here we have regarded as anomalous; *i. e.* taking former observations into the question, of which more will be said presently.

Proceeding about thirty miles farther west, the temperature fell to 4° above ocean temperature, and at eighteen farther, (which was exactly on the end of the bank,) it was $60\frac{1}{2}$° or ocean temperature; and from that point to the western edge of the

bank (in latitude 35½) a distance of about 76 miles, the mean of different temperatures was just 60°, or ocean temperature; that is, 62, 58, 60, 60.

But, getting off the bank and into the water of the current that passes round, it was on its way going up to the northward, and was at 64°, or 4° above ocean temperature, and so continued northward to 35° or more.

[It may be best to mention in this place, as bearing so closely on the other, that Dr. Davy, when near the western edge of the bank, in about 36° S., and near the place where Captain Hamilton left the bank, and had 4° above ocean temperature, Dr. Davy had 66° in the beginning of June, or 5° above ocean temperature, which is very consistent and satisfactory. Captain Hamilton, in going westward, found the same temperature of 4° above ocean temperature to extend 55 miles or more from the nearest point on the edge of the bank.]

Captain Alsager of the Waterloo, in the same year with Captain Hamilton, but 4 months earlier, (*i. e.* beginning of March instead of beginning of July,) came into the neighbourhood of the track of Captain Hamilton, at the distance of about thirty miles more to the southward, off Point Padron. He came on a line of about W. 15° S., and, in consequence, within the *ocean* current: but Captain Hamilton came down from latitude 32°, on a course of W. 36° S., and therefore came in the *Mozambique* current, as we have before said. The temperatures of the two differed considerably in their proportion to ocean temperature; the

Mozambique current being from 7° to 8°, but the ocean current 4½° to 6°, before the admixture of the two streams, and then he had 8° and 9°, like the other, and which continued to the eastern edge of the bank, where it turns southward. Crossing the bank, in 35° to 35½°, he found, just within the eastern edge, 3° above ocean temperature, but farther on only one degree, thence on the middle itself 4°, and near the western edge, in 35°, two and a half degrees.

Captain Alsager found a strong current within the eastern edge of the bank, and within the usual limit of it; but across the bank, generally, there was, in effect *no* current, as E. 8′ was the amount.

It has been remarked, that Captain Hamilton's four degrees, four months afterwards, was in much the same quarter of the bank. Dr. Davy's line is confined to the eastward of the bank; and his course was eastward, tracing the current upward between the parallels of 36° and 35½°. He had crossed the bank in the parallel of 36°, where it is about 170 miles in width.

We suspect that the ship's longitude, at that time, was 10 to 12 minutes too far east; as the 61° of temperature, which was that of the ocean, assumed to be on the edge of the bank, lies somewhat to the eastward of the position generally taken for that of the eastern edge of the bank. That position, however, we shall adopt in this place; as 22° 40′ E.

His first observation of warm water was 71½°, or 10½ above ocean temperature, at sixteen miles to

the eastward of the former, but may have begun immediately after the 61°.[1] This is the highest temperature above ocean temperature that we have found in these journals. Captain Alsager having only 9° at about forty miles farther to the N.E. or higher up the stream; for we are to conclude, that Dr. Davy entered the Lagullas stream between the temperatures 61° and $71\frac{1}{2}$°; and that, steering E. by N. or nearly parallel to the course of Captain Alsager, to 21° east, but towards the opposite quarter. The two routes were generally no more than from 20 to 30 miles distant from each other, and sometimes only 10 to 12; Captain Alsager being to the northward of Dr. Davy's, and Captain Hamilton to the northward of Captain Alsager.

Dr. Davy, in the course of twelve miles from the $71\frac{1}{2}$°, or $10\frac{1}{2}$° above ocean temperature, had $9\frac{1}{2}$°, then 7° to 6° through two degrees of longitude; then from 3° to ocean temperature through the course of one degree; and finally, through one degree more, (to 28° of longitude) $5\frac{1}{2}$° to $6\frac{1}{2}$°.

If we compare this with Captain Alsager's and Captain Hamilton's experiments, and reversing it to make the comparison clearer, it will stand thus:

Dr. Davy	6	6	7	$9\frac{1}{2}$	10
Captain Alsager	$4\frac{1}{2}$	$6\frac{1}{2}$	7	9	9
Captain Hamilton	8	8	8	+	+

It may be concluded that Captain Hamilton

[1] And from hence his course was about E. by N. to about 28° of east longitude in latitude $35\frac{1}{2}$°.

was always in the water of the Mozambique channel; Captain Alsager in the mixed current; and Dr. Davy in the ocean current in the first two instances.

This is the sum of the intelligence respecting the temperatures of the current-water from Natal to the eastern edge of the bank, between latitudes $32\frac{1}{2}$ and $36\frac{1}{2}°$, and which affords a most satisfactory view of it.

Before we pursue the temperatures of the main current farther to the southward, it will be proper to give the remaining part of the observations of the temperature on the bank; the subject of the bank and its currents being, after all, the most important part of our researches; since it is meant to prove how little the current across the bank is to be depended on as an aid when adverse stormy winds from the west prevail.

Here it seems proper also to mention, that Captain Alsager, in the preceding year, two months previous, and in that part of sea west of Captain Hamilton's route (*i. e.* beginning of March being compelled, by foul easterly winds, first to cross the western part of the bank, north-easterly, to as high up as 35° 40′, in the very middle of the bank, and afterwards S.S.E. to the southern extremity of it, he found, both in his way up and down, temperatures little above those of the ocean; and that Captain Hamilton, in the beginning of July, that same year, found only about $2\frac{1}{2}°$, in latitude $36\frac{1}{2}°$, on Captain Alsager's line S.S.E.-ward, where that gentleman had little, perhaps 1°, above

ocean temperature; but, in advancing on the former easterly course, to within a short distance of the eastern edge of the bank, and of course into the strong southerly current, he found the temperature rise to $4\frac{1}{2}°$ above ocean temperature, as might have been expected.

Here we have, upon the whole, a clear manifestation of the nature of the currents over the bank.

Description of the Current, continued.—Although the main body of the stream is turned aside, as we have already noticed, from its general westerly course to one very much southerly, by the opposition of the side of the bank, yet a large portion of it comes over the edge of the bank, in some places, to twenty or more miles within the border, in 100 to 120 fathoms, and with a velocity of 44 to 46 miles. There is, also, one instance of 49 miles, S.W., at a much greater distance within the border; but as this occurred between two stations, the one of which was 12 or 13 miles, the other between 80 and 90, within the edge of the bank, it cannot be known during what part of the day's run the current may have prevailed; but it must have been doubtless much farther in on the bank than the arm of the above example. But this is the only instance of the kind, and may be considered as anomalous.

It will have been seen that the check given to the Lagullas Current, by the eastern edge of the bank, does not turn it absolutely aside at once; so as to compel the whole of it to run along the

edge of the bank, or to give it the direction of that edge: but that it does, by degrees, acquire that direction, and that a considerable portion also of the main stream passes over, and to some distance, within the edge of the bank, and more particularly as it goes southward, where the water on the bank becomes deeper. It must, therefore, be conceived that there is a certain depth of water required for the passage of the main body of the stream.

By the examples one might conclude that the bank, with a depth of about 100 fathoms, did actually turn the stream as the stray current advanced; whence it must be inferred, that its main body is, at least, 100 fathoms in depth. No other reason appears why it does not pass directly across the bank, in the line of the slow westerly current; where the shallowest depths are from 40 to 50 fathoms[1].

Soundings were obtained by Captain Birch in 258 fathoms, in the parallel of 36° 38′;[2] and $8\frac{1}{2}$ miles to the W.N.W. of this station he had 173, and at 11 miles farther to the west 145. Here, then, in the course of 19 miles, in a direction

[1] Qu. *Bank-Edge?* Since every part of the ocean has a bottom, a bank should be that within reach of ordinary soundings; say 170 fathoms and discoloured water. In the present case, the bank-edge, as concerning the body of the current, should be, in effect, the depth at which it stops the body of the current; say 100 fathoms.

[2] In longitude about $22\frac{1}{2}$ E., as shown by the chart.

across the south border of the bank, the depths varied 113 fathoms.

It must be observed that the above description relates only to the main body of the stream, since a large portion of it is diverted to the west and S.W., spreading in a fan-like shape over the bank, in all directions from west to S.W. by S.; and, after having crossed over the bank to the western border, it passes along it towards the N.W., but having a small degree of velocity compared with the main stream. That part which proceeds westward over the bank, between the parallels of $34\frac{3}{4}$ and $35\frac{2}{3}$, appears to be formed generally of the northern part or border of the *main* stream, which, by passing to the north of the angle where the bank turns suddenly to the S.S.W., avoids that encounter which turns the rest to the southward and passes onward, on its original course, between the W. by S. and W.S.W.; spreading itself to nearly a degree of latitude in breadth, but with a reduction of about three quarters of its original velocity. This, therefore, appears to be the cause of the westerly course of the current across the northern part of the bank; whilst, on the southern part, it is generally south-westerly; as being formed of off-sets from the main body of the current, in its passage to the S.W. and this part is generally stronger than the northern part.

That portion of the stream which passes round the bank and over the deep water at its southern extremity, and finally passes along and over its

western edge towards the N.W., although stronger than that which passes across the bank, bears no comparison, in velocity, to what passes down the east side: being, indeed, no very large proportion of the great Lagullas stream.

When the water of this exterior current is united with the waters which pass westward across the bank, which takes place opposite the Cape of Good Hope, they collectively form a wide stream running to the N.W., at the rate of a mile or a mile and a half in the hour, and which is perceptible as far as the parallel of 25° south; where it becomes blended with the N.W. current produced by the S.E. trade-wind.

On the S.W. quarter of the bank, between the meridians of the Quoin and Cape Infanta, the current appears to form eddies setting in different directions at different times, with a slow motion;—or, it may be no more than the errors of reckonings.

Here, too, the easterly current from the South-Atlantic passes at no great distance from the bank; and appears often to disturb, and absolutely impede, the opposite current round the bank, being by far the most powerful of the two in this place; and probably the cause of turning the Lagullas current to the eastward, after the eastern side of the bank has already turned it from a westerly to a southerly direction[1].

COUNTER-CURRENT NEAR SHORE.—*As an adjunct to the description of the current from Cape Recife*

[1] But we have too few observations along the south and S.W. sides of the bank to speak decisively on this point.

westward, it may be observed, that the direction of the shore, beyond Cape St. Francis, westward, changes several points to the northward of west; and the current, in consequence, after passing Cape Recife and Cape St. Francis, bears off the shore in a like proportion, leaving a wide space to the northward of it, which, of course, is free from westerly current.

By this falling back of the coast towards the north of west from Cape St. Francis, together with the falling back of the coast to the N.E. from Cape Vaches, on the other hand, a considerable bay is formed between Cape St. Francis and Cape Vaches. The northern border of the westerly current forms generally the chord of this curve or indentation of the coast, by which the waters of this bay are left free from the opposition of the westerly current. But, as ever happens under such circumstances, the space so unoccupied by the main current will be subject to a *counter-current*. In the present case, the direction and form of the land within Cape Vaches induces, in the first instance, a N.E. current branching out from the westerly current; and which the subsequent trending of the coast to the eastward turns the current towards the same quarter, proceeding all the way to Cape St. Francis, where, by the form of the land at that cape, it is again thrown into the general westerly current. This current, though weak, proves inconvenient to ships that find themselves in it, more especially if they become embayed during the continuance of a strong westerly wind.

The limits of the space southward in which this easterly current prevails, appear to vary considerably, and may probably be regulated by the position of the border of the exterior or main stream. It has been found in great strength as far south as to be considerably within the space occupied by the main current at other times; that is, in latitude 34° 50′, between the meridians of $23\frac{1}{2}°$ and $24\frac{1}{2}°$.

Captain A. Hamilton, of the H. C. ship Bombay, who has been twice in this tract of easterly current, found, in July 1820, that, with the easterly current, the temperature of the sea was very much lower than with the westerly one. The difference was about 7 or 8 degrees, or from ocean temperature to 7° or 8° above it. Perhaps this may be accounted for from this recess being filled with water that, from its slow movement, has had time to cool to ocean temperature: or, that a great proportion of the space was filled by still water, of ocean temperature.

The knowledge of the fact is even more useful than curious; as it may serve to determine, when in this quarter, and particularly at critical times in the night, the nature of the current in which the ship happens to be at the time.

2.—The EQUATORIAL CURRENT and its BRANCHES.

[Charts I. and II.]

The Equatorial Current, as already shown, (pages 22, 45,) is formed of the *drift* water impelled

to the north and N.W. by the S.E. trade-wind ; and runs nearly along the two sides of the Equator, but chiefly along the south side. Its commencement may be fixed at about two or three degrees of south latitude, and between the second and eighth degrees of east longitude : or, in other words, opposite to the island of St. Thomas. The winds near the coast of Southern Africa being very much southwardly, impel the waters towards the *Bight of Benin;* but that bight, as well as the coast of Guinea in general, being occupied or bordered by the Guinea current, the waters are turned westward, and form the northern side of the Equatorial stream. The S.E. trade-wind becoming more and more easterly as we advance westward, so the waters, impelled before it, fall in successively more and more to the west; forming at length a mass which, in some places, and during the sun's being high in the northern signs, is five degrees of latitude in breadth, and runs with great velocity. Its water is commonly two or three degrees cooler than *ocean* temperature in that part, owing to its being brought from a more remote and colder parallel; that is, through the region of the S.E. trade.

At about the 23d degree of west longitude the Equatorial current divides, as before explained, into two branches, the one to the W.S.W. or S.W. by W., the other to the northward. The southernmost and largest branch is afterward subdivided into two by the projection of South-America, *Cape St. Roque*, &c. ; the northernmost subdivision, which

is the middle branch of the stream, taken at large, is the largest and most rapid. This, of course, proceeds along the *northern* coast of Brasil, the other along the *eastern* coast of the same country. The former proceeds uninterruptedly to the *West-Indies*, the latter is traced to *Terra del Fuego:* both receiving constant fresh supplies from the *drift* water of the different regions of the trade-winds through which they pass.

The position of the northern coast of South-America, being much to the northward of west, determines, of course, the direction of the great middle branch of the Equatorial stream; and which is of very great breadth and great rapidity. It passes through the different channels between the Caribbee Islands, but diminishes very greatly in velocity to the northward of Martinique and Dominica. It is difficult to say, either of this current or any of the other streams, how much the proportions of *fresh drift* water received by the way may be to that of the original stream: but probably the greater of the two.

I have here spoken of the Equatorial current as it will commonly be found; but it is subject to great variations and to absolute *anomalies,* as shown in the preceding chapter. (*See page* 67.)

The northern Brasil current is very much stronger during the season of easterly winds than in the other; a sure proof how great a share the wind has in the regulation of the current.

A vessel proceeding from Sierra Leon to the Maranon will, at the proper season, be able to

make a direct cut across; as the N.E. winds will then blow. In the monsoon season you must stand to the southward, and into the S.E. trade; and that trade is then rather south than S.E. It is proper to remark that, at all times, that trade is very much southerly towards Africa; very much easterly towards America. I think, at the Equator the longitude of 20° W. is about the limit where the S.E. trade begins to be much more easterly in going westward; and more southerly in the contrary direction [1].

Wherever you may set out from, on the side of Africa, you will have to cross, first the Guinea current, (*easterly*,) and then some portion of the Equatorial current which brushes the former and runs westward.

In the direct route from Sierra Leon, towards the mouth of the Maranon, the Guinea current is first to be *recrossed* to the westward; and afterwards, a second stream of easterly current which unites with the Guinea current. This is formed from the drift-water of the N.E. trade-wind, in the quarter situated to the south and S.W. of the Cape Verde Islands: but which, being opposed by the N.W.

[1] The effect of the S.W. monsoon, on the coast of *Guinea*, appears to extend from the coast of Sierra Leon to the S.W. or W.S.W. and northward to the neighbourhood of the Cape Verde Islands.

Along the south coast of Guinea, from Cape Palmas to the Bight of Benin, the wind is dead S.W. and south, and it also affects the S.E. trade-wind to a very great distance southward, by changing it to a S.W. or S.S.W. or south wind.

branch of the Equatorial stream, is turned to the S.E. and east, and thus becomes an adjunct of the North-African stream, or that which originates in our parallels. Or, to simplify the subject, the one may be reckoned the southerly stream *within* the Cape Verde Islands; the other, the southerly stream *without* them.

If your course from Sierra Leon be made much to the south of west, so as to reach the parallels between $5\frac{1}{2}°$ and $4\frac{1}{2}°$ N. between the meridians of 15° and 18° W. you will find the current to the north of east. In effect there is an adverse current to your general course the whole way from Sierra Leon to the meridian of 25° W. unless you stand much to the southward; for the Equatorial current, even during its strength, is seldom found to the northward of $2\frac{1}{4}°$ to $2\frac{1}{2}°$ N. but extends to 3° or 4° S. And, if you should leave Sierra Leon when the winds are commonly baffling, within a few degrees north of the Equator, I should at once advise you to stand to the south, cross the Equator, and take advantage of the S.E. trade.

The N.W. Branch of the Equatorial Current, which separates in about longitude 23° as aforesaid, is traced, at common times, as far north as 18°, and sometimes even as far north as 30°. It appears to be, at least, eighty leagues in breadth, but not of rapid motion; perhaps less than one knot at a mean, and runs nearly in the direction which the N.E. trade admits ships to take; in their progress northward, it is often a great help. I am unable to account satisfactorily for the cause of

this great derivation from the great *trunk-stream* of Equatorial current, unless it be to supply the waste of water, by evaporation, within the tract occupied by the *warm* water of the Gulf-stream; in effect its *recipient;* and the supply of the Mediterranean Sea.

The space between the *western border* of the N.W. stream, and the coast of America opposite to it, is, at a mean, 1,000 miles in breadth; and the general motion of the surface within it is to the north of west; influenced, no doubt, by the position of the coast of America, which may be taken at nearly three points of the compass to the north of west; or, more correctly, about W. 31° or 32° N. between Cape St. Roque and Trinidad. Beyond the reach of the influence of this coast, that is in latitude 17° or 18°, the direction of the current is nearly west; and between 19° and 20°, bears rather to the south of west. These currents, in the space between the N.W. Equatorial and the middle Equatorial, that is, in the ocean at large, are weak; being little more than the amount of the *drift* before commemorated.

Inconvenient as the Equatorial streams may appear to navigation, yet circumstances may be imagined under which they would have proved infinitely more so. It is remarked, that the border of the S.E. trade-wind, towards the Equator, is found, at a mean of the whole year, in $2\frac{1}{2}$ degrees of north latitude; and that of the N.E. trade-wind at $7\frac{3}{4}$ degrees: so that the *mean breadth* of the interval between them is more than five degrees, and

the extreme breadth seven. Now, had the approximating point of South-America been at the Equator, instead of 5° S., the current in question would have taken its course precisely through the interval of calms and variable winds; the consequence of which would have been, that ships would have been left completely at the mercy of this Equatorial current, without the general aid of commanding winds; to which may be added, that the frequent recurrence of *southerly* winds, within this interval, would at least have rendered the passage southward still more difficult and tedious.

As the matter stands, the northern border of the current only just reaches the mean point of the south-eastern trade-wind; so that, in the passage southward, they have a prospect of a commanding wind at the same time with the current: and, provided they cross the Equator to the westward of the 20th degree of longitude, the wind will not be to the *southward of S.E.* even in the southerly *monsoon* of this tract.

And here it is highly proper to state that the meridian line of 20° W., is the line of separation (in the quarter towards the Equator, and in the just mentioned season,) between those winds that are more or less southerly, or easterly: that is, to the *eastward* of it the wind is seldom so far to the east of south as S.S.E.: and, on the *westward* of it, it is S.E. or E.S.E. This is a fact which cannot be too strongly impressed on the minds of navigators; and the journals of the Grenville, and of Captain Grant's ship, may be cited in proof of it.

This state of things is clearly referrible to the state of the seasons in that quarter. The southerly *monsoon*, then (June and July) at its height, extends its influence to that distance westward; though probably not far to the southward of the Equator.

The Grenville entered the Equatorial current in lat. 3° N., longitude between 9° and 10° west. She met the S.E. trade-wind at the same time nearly; but that being often south, and seldom to the eastward of S. by E., she made no better course than W. 30° S. from the place of entering the current to the place of leaving it, which was in lat. 4½° S. long. 21½° west: a *run* of 270 leagues; including the effect of the current, which was 130 leagues.

Captain Grant, in 1800, crossed the Equator in 20½° long. west, with the wind at S.E. (in May); and, *keeping a point from the wind*, reached in 17 days, (from a common point of departure with the other ship,) a station which was only 40 leagues to the westward of that which the Grenville arrived at in 42 days. So that 120 miles was all the distance that was gained by a delay of 25 days, and a *detour* of 200 leagues: besides encountering adverse currents on the coast near Sierra Leon, &c. More need not to be said against crossing the Equator to the eastward of longitude 20° W. at that season (June and July) at least.

Equatorial Current, continued.—It has already been stated that this stream owes its origin to the accumulation of the waters of the

drift currents, set in motion by the S.E. trade-wind; and more particularly to that part of it which, in the neighbourhood of the coast of Southern Africa, blows nearly parallel to the coast, and thereby occasions a northerly or along-shore current: moreover, that this wind becomes a S.S.W. or S.W. wind in the recess of the Ethiopic Sea, and thus forcing the water into the recess, occasions it to turn to the N.W., the only quarter by which it can escape.

Had not the body of the Guinea current already occupied the space next to the shore of Guinea, it is unquestionable that the waters would have been forced up to that coast; and that the Equatorial current would have commenced on the north, instead of the south, of the Equator: but the Guinea current having the power of preserving its *place*, operates on the waters from the south much as the coast itself would have done had it been accessible.

As the Lagullas current is perceptible to the height of 26° S., and as a portion of it points towards the coast on the N.E., there can be no doubt of the continuity of it far within the verge of the northerly drift current, into which it, of course, merges. But we have no detailed accounts of the circumstances of the currents along-shore, between the parallels of 28° and 11½° south, although the existence of such is well known; so that the continuity of the thread of current is never broken between that in the Indian Sea and the Equatorial

current. The first notice, from authority, of a current hereabout, is its issuing from the deep recess of the coast of Benguela, between 9½° and 11° S., in a W.N.W. and N.W. by W. direction, (as if water had been forced in there,) and with a rate of 14 to 25 and 30 miles per day.

From the just mentioned Bay of Benguela the current ranges along the coast to the N.W., receiving the waters of the Zahir or Congo River, the outfall of whose waters runs nearly in the same direction with the sea current, that is N.W., and only marks its character by the increased velocity of the stream, and the lowering its temperature.

The stream of this N.W. current, between 11° and 9° S., is at first narrow, but, by its constantly receiving new supplies from the southerly wind, it widens as it ranges up towards Cape Lopez and the Isle Anno Bon. It is in this quarter of Anno Bon, between the first meridian on the west and the coast of Congo on the east, that this N.W. current (which may be near that deemed the incipient *Equatorial current*) meets, and mixes its waters with, the Guinea current from the North-Atlantic: the N.W. being occasionally felt to the northward of St. Thomas's Island, and that of Guinea in 4° or more south: of course, they in turn usurp each other's boundaries. In effect, from a point on the Equator one degree west of the first meridian, in an E.S.E. direction, to the parallel of 4° S. or beyond, the Guinea current is occasionally found; as is the N.W. current to 1° of north latitude within

the same extent east and west. But the N.W. current generally prevails; and doubtless, at all times, within seventy miles of the coast.

It appears that the Guinea current advances to the S.E. in August and September, but in March and May it has reached 2° and 3° south.

We shall now proceed to trace, in a cursory way, in order to bring into one point of view the general boundaries of this vast stream, as far as they are known: and where only *partially* known, to endeavour to supply the defect as far as such knowledge may be useful to the reader.

Its origin has been taken to be in the quarter of Anno Bon, and south of the Equator; and that, when in its strength, its northern boundary comes up to the north of St. Thomas's Island, or to beyond the parallel of 1° N. Continuing its course westward, its northern boundary ascends to the parallel of 1° 45′ on the meridian of Cape Palmas, although it had previously reached to $2\frac{1}{2}$°, owing to the recedence of the coast of Guinea to the north in that part, giving freer scope to both currents: for, in this quarter, they *brush*, and sometimes press, each other in their opposite courses; and, also, occasionally usurp each other's limits.

A second, and much quicker, recedence of the coast on the west of Cape Palmas, produces, in the first instance, a like effect with the former; and, soon after, a great divergence of the borders of the two currents from each other, between 11° and 14° W., occasions an *eddy*, in which offsets from the

two currents run in various directions, but chiefly from the Equatorial to the northward.

The extreme northern border may from thence be traced westward, between the parallels of 3° and $3\frac{1}{4}$° N. to 18° of west longitude, when it begins to decline somewhat to the south; so that, in longitude 22° it is below $2\frac{1}{2}$°: and about this point it is that the division of the Equatorial current into N.W. and S.W. branches takes place.

This northern edge of the Equatorial current, which we have thus traced, is better known than the southern; because the former and the Guinea current running in opposite directions, and generally very near to each other, mark the common boundary of both. On the contrary, all the southern waters that fall into the Equatorial current direct their courses to the N.W., so that the boundary can be only approximated in that part, as far as it is known by a reference to the velocity.

Beginning with the southern boundary on the west of Anno Bon, about where the first meridian cuts the Equator, the breadth of the N.W. current, the Equatorial, has not been observed to extend farther to the south than about $1\frac{3}{4}$° or 2° S., and having there a general N.W. course, so that it cannot be reckoned here of a greater breadth than 160 miles from N.E. to S.W. Here the velocity is from 13 to 25 miles, and a thread of it may be traced from 10° and 11° S.

From hence going westward, south of the Equator,

the space is generally blank on the chart, from want of ships' tracks, until we arrive at the eighth degree of west longitude (or nearly opposite Cape Palmas), where two tracks cross the equatorial current obliquely to the S.W., in August and September, in different years. One was Captain Cook's, the other an East-India ship's. The former reckoned, at a medium, a current of 30 miles per day between the Equator and $4\frac{1}{2}°$ S.; the other from 35 to 63 miles. The direction of the stream varied from west to W.S.W., although on the north of the Equator it was running W.N.W., because, as we have said, the receding of the Guinea coast to the northward took place there.

A second blank follows, from the last place of crossing to 16° W., in which nothing is known between the Equator and 3° to 4° S.; but in the space beyond that to the westward, being in the common track of ships, both out and home, and on both sides of the Equator, the proper form is complete.

Respecting the position and direction of the southern part of the Equatorial current, from about the first meridian and parallel of about 2° S., and of its southerly boundary, through the unknown space above mentioned, this is the Author's opinion: That, from about the first meridian, and in about 2° S., the southern edge of the stream runs much westerly, or perhaps a point to the north of west. [*See Chart* I.] That afterwards, from the constant accession of N.W. drift, (as is proved by the direction of the drift currents of Mr. Fitzmau-

rice in the Congo,) along the parallels of 4° and 5° S., it gradually increases in breadth until it spreads out to 4½° S. in longitude 14° W., as Captain Cook found it; but it must be observed, that he found its northern boundary, at the same time, but little to the north of the Equator. The Indiaman, in a subsequent year, found it extending to 1° N., and equally to the southward.

In order, then, for the southern edge of the stream to reach the latitude of 4½° S., it must have deviated from west, or west a little northerly, to a point and a half to the south of west: and this appears perfectly reasonable from the constant influx of drift current during a course of 750 miles, so as to render a parallel course impracticable from the addition constantly making to the width of the stream.

From the point of 14° west longitude, where Captain Cook left it, in 4½° S. the southern edge of the stream goes much westerly till the separation of the N.W. and S.W. branches, and the higher rates of motion continuing to 4½° and 5° S., beyond which, southward, they are much lower. At the same time, the high rates of northerly current continue to 2½° or 3° N. on the opposite side of the Equator: whence from seven to eight degrees in breadth, or 450 miles, may be taken for the width of stream, before its separation into N.W. and S. W. branches; although no more than 160 miles at its origin.

But wonder will vanish when it is considered that, since its formation it has ran a course of

1200 miles, and during that whole interval has been collecting the drift currents raised by the S.E. trade-wind; or, rather that trade-wind *nominally*; for in the quarter towards the east it blows from S. by W. to S.S.E. during two-thirds of the way. It is also to be remarked, that it receives no supplies from the north side.

Thus we have endeavoured to sketch an outline of the Equatorial current from its origin to its division into N.W. and S.W. branches, in about 22° of west longitude, and shall next proceed to trace the S.W. stream (or proper Equatorial) from its point of separation to the Caribbean Sea, leaving the *N.W. branch* to future discussion, as it will receive some elucidation from its connexion with the recipient of the Gulf-stream.

The main body of the stream, now properly *Equatorial*, has a breadth of more than 300 miles. The stream, as it approaches the meridian of Cape St. Roque, changes its course from south-westward to west, in conformity to the trend of the coast. On reaching Cape St. Augustine, a small proportion is separated from it by the intervention of that cape, and falls on the eastern coast of Brasil; whilst the main body proceeds along the north coast of the same country in its way towards the West-Indies.[1]

[1] The part which falls on the coast between Cape St. Augustine and Cape St. Roque, bends up to the north of west, at some distance short of the coast, whilst the current near the shore runs along shore to the northward, not only from Cape St. Augustine itself, but from some distance to the southward of it; and, in July, &c., that part of it appears to be the point of division

We have no data, from authority, for any particulars relating to this current through its long course along the north coast of South-America to the Caribbean Sea. But public report and universal consent sufficiently establish the fact of there being a strong current, estimated at two miles per hour, in certain places, and still stronger where it passes by the island of Trinidad.

Sir James Yeo, in 1816, in his route from Guinea to the West-Indies, sailed at too great a distance from the land to be within the verge of the stream; but what appears surprising is, that no westerly current (or drift) should be at all noticed by him in his course of more than 500 leagues through the N.E. trade, between the Equator and Barbadoes! (*See page* 67.)

But he met with a current which may be regarded as the continuation of the outfall of the river Maranon, at about 500 miles to the north-eastward of the mouths of that remarkable river: much the same as Captain Beaufort and others did the outfall of the river Plata, (described hereafter); and probably, also, like that, *crossing over the sea-current.*

The water is forced through the different channels formed by the Caribbee Islands, into the sea of that name, by the trade-wind, which is there very far *easterly*. The directories state, that the *strongest* of these streams (next to the current by Trinidad,

between the two currents near the shore. It is reported to be otherwise during the N.E. winds, but of this the Author has no particular knowledge.

the continuation of the Equatorial,) is that between St. Vincent's and St. Lucia; after having stated that between Trinidad and Granada, at a mile to a mile and a half per hour. Captain Rodd, in his voyage to Jamaica, found it to set twenty-one miles per day, or nearly one mile per hour, on the west of the opening between St. Lucia and Martinique, and in direction north-westerly; and the Pique had 8 to 10 miles per day, W. a little S., on the north of the Virgin Islands.

The inset into the Caribbean Sea, indeed, appears to be almost universal through all the passages of the vast chain between Trinidad and the Bahamas.

This Equatorial stream, from its origin near Anno Bon to the entrance of the Caribbean Sea, has a course of, at least, 4000 geographic miles: but then it is quickened or *renovated*, throughout its progress, by the drift currents, first of the S.E. trade and then of the N.E.; whereas the Gulf-stream, which has occasionally an equal length of course, receives very little addition to its velocity from the drift currents of the westerly winds.

We come now to speak of the rate of velocity of the Equatorial stream.—It has been already observed, that we are ignorant of all details between the latitudes of 28° and 11° S., but that it is well known that the southerly wind, which ranges nearly parallel to that coast, on the west of Southern Africa, sets a strong current in motion to the northward: and accordingly that, in about 11° S. the most southern point known, a current is

found setting to the N.W. or nearly in the direction of the coast in that part; and seems as if it arose from the escape of the water forced into the great recess between Cape Negro and the river Congo. This current varies in strength from 14 to 25 and 30 miles per day; and from hence a thread of current of 20 to 25 miles per day, and in one instance 30, may be traced to the N.W. to the quarter of Anno Bon, the supposed origin of the Equatorial current; although the body of the stream may not, generally, be more than 13 to 16 miles.

In its progress towards and opposite to Cape Palmas, it has been noted as high as 52 to 63 miles in *August*, which might be owing to the mutual pressing of that and the Guinea current on each other: as in February, (a quick season of both currents,) 25 to 35 miles were found.

Between 10° and 16° of west longitude, and north of the Equator, at the end of June and beginning of July, it runs from 44 to 79 miles per day: and this is by far the strongest part of the whole stream, from any communication that has come to the Author's knowledge; since it ran 262 miles in four days, equal to 65½ per day at a medium. But this can be regarded only as casual, and was probably again owing to the pressure of the two streams on each other in a season of fulness, and in a part where they are straitened for space by the projection of the land about Cape Palmas.[1]

[1] The S.W. winds that blow into the Ethiopian Sea, during the

There is a similar example in the same stream in the quarter toward Cape St. Roque, where a retrograde motion of a part of it to the eastward occasioned a *pressure* on the remaining part of the stream, which kept its natural course, and the western stream ran eighty-eight miles in the twenty-four hours. This happened at 80 to 100 miles N.E. by N. of St. Pedro's Islets in the month of May, at the same time that an *easterly* current of thirty miles ran between the two places.

However, although this great degree of velocity may be regarded as casual, yet the first appearance of the Equatorial current, in any degree of strength, may be placed between 8° and 11° west; that is, not far to the S.W. of Cape Palmas.

The detail of the Equatorial current is best known between 16° and 30° of west longitude on the north, and to 35° W. on the south, of the *Line;* within which space the separation into N.W. and S.W. branches takes place. For it is within these limits that the general courses of ships lie, and the examples are more numerous than ten charts would contain. The rate is commonly stronger near the Equator than at a distance from it; and stronger on the north than on the south of it. Moreover, the season affects it in some degree, though not so much as might be expected. It is certainly strongest when the sun

season when the sun is far to the north, increase the rapidity of the stream, (as in May, June, July, and August,) and it is then in its greatest force. From October to March it is moderate, sometimes very weak.

is far in the northern signs, in the months of June, July, and August, and at that time comes up farthest to the north; and weakest when the sun is far in the southern signs; that is to say, in December, January, and February.

The examples vary among themselves in point of rate, as may be supposed, exceedingly: they rise in very many instances to 45 and 50, occasionally to 60, miles in twenty-four hours: but perhaps the mean may be taken at about 28. After the separation into N.W. and S.W. streams, the latter (now the proper *Equatorial*) runs rather stronger towards Cape St. Roque, and also more equal: perhaps the mean may be taken at 30 or more. Near the Roccas it ran $2\frac{1}{2}$ knots per hour in October, being perhaps straitened by rocky banks under water as well as above, and it now takes a westerly direction to pass Cape St. Roque. That portion which is separated to the south by the land of Brasil grows much weaker.

There are few authorities for the rate of this current along the north coast of South America to the Caribbean Sea. The N.W. stream continues strong immediately after its separation, but soon after slackens. More will be said concerning it hereafter, as the termination of the Gulf-stream, &c., has some bearing on it. The S.W. stream (or proper Equatorial) is known to run very strong, generally, but more particularly after the falling in of the Maranon: two or three miles an hour are said to be its rate, which is yet increased by the Orinoco, making a prodigious stream into the

Caribbean Sea, on both sides of Trinidad. It proceeds thence along the Colombian coast into the Mexican Sea.

Thus we have attempted to delineate the progress of this mighty stream, from its origin in the Bight of Guinea to the Caribbean Sea. Its effect on the courses of ships that cross it, by carrying them rapidly to the westward before they could get to the south of Cape St. Roque and Cape St. Augustin, has, in a course of time, defeated well concerted plans by delays; and, by keeping troops too long exposed to unwholesome latitudes, it has caused the loss of many valuable lives. For the only remedy must be to tack to the N.E. with a *strong lee current*, and make a second attempt to get southward, which must, necessarily, cause great delay.

However, the present state of our ships, in respect of constitution and equipment, is such, that, with the increased knowledge of the navigation, and perhaps, above all, the facility of finding their place by celestial observations and chronometers, which warn them fully of their situation in time to arrange their courses, for avoiding hazards of every kind, will render it unlikely that mistakes of the above kind should happen in future. The only danger is, that a total stranger to the navigation, who may rely on the superior quality of his ship or crew, may despise caution, and suffer accordingly.

The Temperature of the Equatorial current is lower than that of the ocean on each side of it.

We shall here cite four different examples of it at different seasons; that is, one with the sun just returning, or declining from the northern tropic: a second, with the sun advancing to, and within a month of the same tropic; a third, with the sun returning from the same tropic, and within one month of the Equator; and, lastly, the sun *vertical* at the Equator.

From these four examples it may be clearly collected, that the cause of the Equatorial stream being of a lower temperature than the adjacent sea, is, that it is formed of water brought from a *colder* region by the S.E. trade-wind; and which is a proof, at the same time, that the said current owes its formation to that trade-wind.

First, of the two extreme cases, in respect of season, reported by Mr. Dalrymple and Dr. Davy, both on their way southward; the one being when the sun was the most remote from the Equator, in the end of June and beginning of July; the other, when the sun was vertical, in March. In the first, in June and July, the temperature had been generally 80°, or 80° and a fraction, to the parallel of $2\frac{1}{2}$° N. Then, entering the Equatorial current, it fell to $79\frac{1}{2}$°, $76\frac{3}{4}$°, 78°, and then 76°, (in $1\frac{1}{4}$° N.,) and at the Equator also 76°. Then, in 1° S. it rose to $76\frac{1}{2}$°, and continued to $2\frac{1}{2}$° S. At $3\frac{1}{3}$° S. it rose to $77\frac{1}{2}$°, near the southern edge of the stream. Finally, in 5° it rose to $78\frac{1}{2}$, and from thence southward, retiring from the sun, it gradually fell.

The line was crossed in about 18° of west longi-

tude, and the whole track across the stream was contained between 12° and 21° W.; so that it was crossed very obliquely.

Dr. Davy's route lay between $18\frac{1}{2}$° and 22° of west longitude, and he crossed the Equator in 22° in March, the sun nearly vertical, and returning, of course, from the southern tropic.

In 5° N. the temperature of the water was 80°; in 4° N. $80\frac{3}{4}$°, and in $3\frac{1}{2}$°, $81\frac{1}{4}$°. [In this part there is an admixture of streamlets from the north and west.] In 3° N., entering the Equatorial current, $79\frac{1}{2}$°; in $2\frac{1}{2}$°, $79\frac{1}{2}$°; in $1\frac{1}{2}$° N. 79°; at the Equator, $78\frac{1}{2}$°. In $1\frac{1}{2}$° and $2\frac{1}{2}$° S. $79\frac{1}{4}$°; in 4° S. about the edge of the stream, $79\frac{3}{4}$°; and, in $6\frac{1}{2}$° S. 80°.

Here then it may be observed that, when the sun was at the greatest distance from the Equator, the temperature at the Equator and at $1\frac{1}{4}$° N. of it, was 76°, whilst beyond the stream, to the northward, it was 80°, or more; and beyond the stream to the southward, $78\frac{1}{2}$°; that is, 4° less than to the north, $2\frac{1}{2}$° less than to the south. There may, perhaps, be allowed on the proportion of the difference of climate between $2\frac{1}{2}$° S. and the Equator, as being $2\frac{1}{2}$ degrees more retired from the sun, somewhat less than a degree; whence the Equatorial temperature might possibly have been 79°, or more; but there is a clear difference of three degrees or more between the temperature of the Equatorial current, where coldest, and the adjacent seas.

In the contrary season, when the temperature at the Equator was the highest, of course the sun being vertical, it is found, in the first place, that

the temperature at the Equator was $78\frac{1}{2}°$, instead of $76°$, as in the former case: and also that this $78\frac{1}{2}°$ was about $2\frac{3}{4}°$ below the temperature previous to entering the stream; as also about $1\frac{1}{4}°$ below the temperature beyond it.

In this case the temperature ought naturally to have been *increased* between $3\frac{1}{2}°$ N. and the Equator, as advancing more towards the sun: so that the difference, in order to compare it with the former example, should be *more* than three degrees. However, either way it proves the same thing; that the difference of temperature of the Equatorial current, from the other, is owing to the influx of the southern and cooler water, brought by the S.E. trade-wind; the whole breadth between 3° N. and about 4° S. being from about $1\frac{1}{4}°$ to 3° lower than the ocean-water on each side of it: and the Equatorial current flows through the whole of the included space.

It may also be observed that, in the season we are speaking of, that is, when the sun is in the Equator in March, the corresponding parallels are much warmer in the southern than in the northern hemisphere, owing to the sun having just left the former; and to this also may probably be ascribed the higher temperature of the Equatorial current, by $2\frac{1}{2}$ degrees, in March than in July.

The other two examples are equally in proof of the above fact. Mr. Fitzmaurice (with Captain Tuckey) crossed the Equator far to the eastward, and in the very quarter where the Equatorial current has its origin, near the island of Anno Bon

and St. Thomas's, where it seldom comes to the northward of the Equator. In the end of May, along the north side of the Equator, and in the Guinea current, between 4° and 7° of east longitude, the temperature was 80°, but soon after, on crossing the line, and entering the N.W. current, it fell to 79°, 78°, 77°, to 1° south; and from 1½° to 2° S. 75°, and in 5° and 6° S. to 76°.[1]

Near the shore of Congo, Mr. Fitzmaurice had it so low as 69° and 70°, possibly owing to the admixture of the river water, and being also in soundings.

Hence Mr. Fitzmaurice's report states a difference of full three degrees in the temperature between the Guinea and the Equatorial currents.

Lastly, Sir James Yeo, from Cape Coast Castle, came near half a degree north of the Equator in the middle of August, and in about 2½° of east longitude, where the temperature was 77°; and, about the meridian of London, he entered the N.W. or Equatorial current, with a temperature of 75°; thence, along the south of the Equator, to 30 minutes south and 5° 21′ W., he had 73°; and thence to 12° 40′ W., in 1° 40′ S., all 73°: to 1° 51′ S., 16° W., 74°; to long. 19½° W. in 2° 9′ S., 76°; to long. 27° W., on the same parallel, 76°; to 1½° S. 30⅓ W., 78; and the same to 0° 38′ N. 35° W.; in 1° 40′ N. and 38° 10′ W., 81°.

Here it may be remarked that, late in August,

[1] It was 78½° in the western part of the Atlantic nearly at the same season, or a fortnight later.

the water south of the Equator was about 4° cooler than on the north, (*i. e.* 77° and 73°,) and that this was regular from about the meridian of Greenwich to $12\frac{2}{3}$° W., in 1° 40′ S., all 73; to 16° W., 74°; and to 27° W. 2° 9′ S., 76°. Thence, recrossing the line to the north, in 32° W., 77° and 78°; and to 38° 10′ W. in 1° 40′ N., 81°.

So that the season comes nearest to Dalrymple, *i. e.* only a month later, August, and the temperature is 3° lower. [Qu. Is this owing to the thermometer alone?]

The temperatures from the meridian of Greenwich to 16° W., at 2° south of the line, and all the way to 27° W., and to the north of the line in 35° W., all serve to prove the same thing; and, as in latitude 0° 38′ N. long. 35° W., they had 80° and 81°, this agrees with fact: for the Equatorial current was then to the southward of them [1].

3.—The BRASIL CURRENT. [Charts I. and II.]

The origin of the Brasil current has been already explained in the southern subdivision of the Equatorial stream, which takes place at Cape St. Au-

[1] The highest temperature in these seas that has come to the Author's knowledge, for any considerable space together, is in the tract adjoining to the windward coast of Guinea, between the parallels of 5° and 10° N., it being seldom below 81°, very commonly 82°, and sometimes 83¼°. This was in the month of June, and may be owing to the periodical currents which prevail there, and which, at that season of S.W. winds and N.E. current, detain the water within a narrow space.

gustin, on the coast of Brasil, in latitude about 8° south. That parallel, to the distance of 300 miles eastward of Cape St. Augustin, forms the division of the currents which run to the north of west towards Cape St. Roque, and those to the south of west to form the beginning of the Brasil stream.

But this stream is of inconsiderable breadth till, increased by the accession of drift current by the S.E. trade, it arrives in 16° or 17° south, where, to the distance of 250 miles from the coast of Brasil, the current runs to the south of S.W., and gradually declines to the southward till it becomes S.S.W., or nearly along-shore to Cape Frio, where its rate was found to be 30 miles per day, at 200 miles from the shore. Here, by the fall back of the land to the W.S.W., the direct current is thrown farther off shore; and, as generally happens in such changes of direction of the coast, a *counter current* in the Bay runs to the N.E. within Cape Frio[1]. Farther to the south, in 30° and 32°, the current is found again to run more westerly, conforming to the trending of the coast, at the rate of 15 to 20 miles per day, and is found at 250 miles from the coast extending to the north of the River Plata.

Here the remarkable circumstance of the passage of the *current of the Plata,* across and over the

[1] To this current may be mainly attributable the melancholy catastrophe of His Majesty's Ship Thetis, in 1830.—Ed.

southerly current, takes place: beyond which, to the south, the Brasil current again appears, and is felt all the way to Staten Land, although slow, as we have previously stated.

The Brasil current, south of Cape Frio, rests on the authority of Lord Anson's Journal, Captain Cook, and the Russian captains Krusenstern and Lisiansky; and the *counter current*, between St. Catharine's and Cape Frio, on those of Captains Krusenstern and Lisiansky, and Captain Torin of the East-India service. The *cross current* of the Plata is chiefly from Captain Beaufort, R.N., but also from Anson and Krusenstern. This current runs first to the east, and then turns to the E.N.E. or more northerly, and was found to set at the rate of 24 miles per day, or one knot per hour, at 590 miles, or nearly 200 leagues, from the north side of the entrance of the Plata, and it ran at the rate of 32 miles intermediately. At its greatest range it was 140 miles in breadth, but there was only a thread of it where it ran at 24 miles, seemingly a continuation of the intermediate 32 miles, as shown in the Chart II.

4.—The SOUTHERN CONNECTING CURRENT.

[Charts I. and IV.]

From between 20° and 25° S. to the verge of the trade-wind, the drift current on the west side of the Atlantic takes a bend to the southward through the whole space, generally, from the coast of Brasil to

17 degrees of longitude east from it, or about 300 leagues, which may probably be accounted for from the quantity of drift impelled to the westward by the trade-wind, and which cannot reach the coast from want of room, and can escape no other way. We have already stated that this accumulated water, passing to the south beyond the limits of the trade-wind, and consequently of the western drift, runs off to the eastward, and is consequently augmented in its way by the prevailing westerly winds, and by drift bending southward, becomes a large stream before its arrival at the neighbourhood of the Cape of Good Hope.

This is a part of the ocean but imperfectly known; so that, generally, between 30 and 40 degrees of latitude, and longitudes 25° and 40° W. is nearly a blank in the chart. However, it appears that another easterly stream, probably a derivative from the Brasil current, about latitude 39°, which Captain Beaufort traced eastward from thence to about 22 degrees of longitude (long. 28′ E.) running, on the whole, east, at a mean rate of 18 miles per day; but there he lost it. It is known that a constant drift or slow current runs to the east or E.N.E. from the island of Tristan da Cunha; and, indeed, every circumstance proves that there is a *general* motion to the east between the parallels of 30° and 40° S., and which, when it arrives near the Cape of Good Hope, is a very wide and strong current; strong enough to run 2000 miles beyond the Cape.

5.—On the Levels of the CARIBBEAN and MEXICAN SEAS, and the ORIGIN of the FLORIDA or GULF-STREAM. [Chart II.]

These Seas, which receive the continuation of the *Equatorial* current and its adjuncts, and send forth that of Florida, or the Gulf-stream, may be regarded as a kind of intermediate lakes between them; and the latter of these seas, as the immediate and elevated reservoir of the Gulf-stream. The supposed cause of this elevation, above the general level of the Atlantic Ocean, has perplexed many persons, in their attempts to account for it; and the difficulty has been increased by their supposing that a very great elevation was necessary, in order to account for the velocity of the stream. But perhaps there is no necessity for supposing any great degree of elevation; nor of any cause beyond what is in constant operation elsewhere, although on a less extensive scale. For, the operation of a constant wind, which forces the surface of a vast expanse of water into a more confined space, may raise the level of the included water to such a height, as to occasion a great velocity of stream at the place of its discharge; more particularly when the opening is *comparatively* narrow; as in the case of the Strait of Florida.

In the General Observations at the commencement of this work, the Author has ventured to offer this opinion, as the cause of the elevation

of these seas: and has suggested that it is the effect of the north-eastern (or rather, in that quarter, *eastern*) trade-wind, combined with the position and direction of the coasts of Brasil and Guyana, between Cape St. Roque and Trinidad: the wind forcing the surface of that part of the Atlantic Ocean towards the West-Indian Seas and the coast of America, by interposing itself, obliquely, to the course of the volume of water in motion, reducing the space so operated on, by the wind, to one-half of its original breadth, by the time that the passing waters arrive at the Caribbean Sea. So that the impelled mass of water, being constantly narrowed in its progress by the lateral pressure of the coast of South America, must, of necessity, be forced up to a *higher* and *higher* level, as it advances; like the wave of tide in the Bay of Fundy, the Bristol Channel, and the Gulf of Cambay. For the volume of water cannot *retreat* when pressed laterally; because, besides the effect of its own *momentum*, it is impelled forwards by the accession of fresh supplies, constantly brought on by the same power which originated the movement.

The *inset* of the continuation of the *Equatorial* stream, into the *Caribbean* and *Mexican* Seas, has often been considered as the cause of the elevation of the Gulf of Mexico; but, as this current is known to originate in the Atlantic Ocean, which ought, of course, to be lower than the outfall of the Gulf of Mexico; and as no current *can* raise a head of water, *higher than itself*, this idea cannot

be entertained, any more than *that* which accounts for it, from the accession of river water; which is much too inconsiderable, in respect of the volume of water discharged. The current of *inset*, into the Caribbean Sea, may perhaps be regarded rather as an EFFECT of *that* which produces the elevation, than the CAUSE of it.

The current above named *Equatorial*, is so called in conformity to popular opinion; but, although a part of it may be such, the great body of current which enters the Caribbean Sea is doubtless raised by the operation of the N.E. trade-wind, on that part of the Atlantic lying generally to the westward of Cape St. Roque. The vastness of its body proves that it cannot be the Equatorial current alone, because that current, (which is formed by the S.E. trade-wind,) divides itself into three parts; of which, as we have shown, only one passes along the northern coast of Brasil. If it is to be considered as the continuation of the Equatorial current, it is rather that current *renewed*, like that of Lagullas, by the south-east trade-wind.

Although the effect of the trade-wind in impelling the surface, or *drift current*, may be, in the first instance, nearly equal throughout the whole *zone* of the trade-wind, yet the parts nearest to the South-American shore, must necessarily be raised higher than the parts more remote; because of the immediate operation of the lateral resistance produced by that shore; and which effect seems to be clearly shown by the increased velocity of

the currents through those channels of the Caribbean chain, situated between the islands Trinidad and Dominica; for the currents there have double the force of those to the northward of Dominica.

For this fact, we have more especially the testimony of Captain Deacon, of H.M. Ship *Niobe*, who had the best opportunities of knowing, from his having been a considerable time employed among those islands. The Spanish work, the *Derrotero de las Antillas*, confirms the fact also, by numerous examples. The Baron Humboldt in the line towards Trinidad, in July, remarks, that the N.W. current increased in velocity, as they advanced towards the coast of South-America. And Captain Rodd, of his H.M. Ship Warrior [1], in May, makes the same remark, in his way from England to Barbadoes. In effect, the existence of a general movement of the surface of the western part of the Atlantic, within the tropic, towards the West-Indies, is well established; not only by common report, and the drift of floating substances towards it, but also by the testimony of the best journals.

In effect, the most elevated part of the great body of water raised by the joint operation of the trade-wind and the coast of America, appears to pass between the Gulf of Paria and Dominica; to the northward of which latter, and between it and Porto-Rico, the currents are weak; as being probably little more than the simple effect of the trade-

[1] Now Rear-Admiral Sir John Tremayne Rodd, K.C.B.—Ed.

wind ; (in other words the *drift current ;*) but the other, as being the combined effect of both.

Currents are also proved to have set into the Caribbean Sea from the Atlantic Ocean, through the Mona and windward passages[1]; so that there is an *inset* into that sea from *every* passage, save on the west, the Channel of Yucatan, through which its waters communicate with the Sea of Mexico.

But the body of the *drift current* to the northward of the greater West-India Islands (Cuba, Hayti, and Porto-Rico[2],) meeting an opposition at

[1] A deficiency of observations leaves the Author in doubt, whether these two currents are constant, or only occasional. From what has been said it must be inferred, that the *Caribbean* Sea is lower in the quarter towards *St. Domingo* and *Porto-Rico,* than on the side towards the continent; as also, that the Atlantic, to the northward of those islands must be higher than its *general* level, from the accumulation produced by the *drift* current of the N.E. trade-wind, and the opposition of the *Bahama* Islands to it. It appears probable that the direction of the currents through the above straits is regulated by the comparative levels of the two seas, with which they communicate. It might be expected that the current through the *windward* passage ran most commonly into the *Caribbean* Sea.

[2] The Spaniards apply the name of *Antillas* to the whole chain of islands between the Gulf of *Paria* and *Florida;* distinguishing the three greater islands on the north, as the *Great Antillas;* and the chain of smaller islands on the east, (to which we exclusively apply the term *Antillas*) by the *Lesser Antillas*. This appears to be an useful mode of classing them : being at once *comprehensive* and *distinct.*

In some old English maps, the term *Little Antillas* will be found applied to the *Caribbee* Islands.

the Bahamas, collects and forms a stream which is naturally turned to the south and east, and running along the north side of that chain of islands, has carried ships so far out of their course, that commanders who, after passing the Strait of Florida into the Atlantic, intended to go through the *Windward Passage*, have found themselves near the Mona Passage, or at the Virgin Islands.

It may, also, be observed that, most commonly, the drift current, formed by the northern part of the zone of trade-wind in this quarter of the Atlantic, is weak; owing to the irregularity and unsteadiness of the wind beyond the parallel of 25°.[1]

It is certain that no *positive proof* can be adduced that the elevated levels of the Caribbean and Mexican Seas are occasioned by the impulse of the trade-wind: yet it fairly may be presumed that such is the fact:—in the first place, because such effects are well known to be produced in other situations; and, also, because it has been known

[1] The frequent unsteadiness of the N.E. trade-wind is so well known, that ships bound to the West Indies, &c. seldom venture to run down their westing much to the northward of 20°. Many instances of great irregularity might be quoted; but an instance occurred in March, 1819, a month in which ships usually carry the N.E. trade nearly to the Equator. The only regular trade-wind, at this time, was between the parallels of $22\frac{3}{4}$° and $28\frac{1}{2}$°; and again, between 22° and 13°. Through all the rest of the space the winds were generally N.W. or west; and sometimes S.W.; and these continued to $2\frac{1}{2}$° south.

that the changes in the velocities of the stream, through the *Florida Strait*, have accorded with the different state of the winds (in respect of their strength) in the *Atlantic;* and still more that the seasons, which regulate those winds, produce also a correspondent effect on the state of the current.

But, although it may be well understood that certain portions of the ocean have the level of their surfaces occasionally raised by the wind, yet this has not been hitherto *proved* in respect of any great expanses of surface. A very satisfactory proof, however, has lately come to the knowledge of the Author. It happened within that wide recess in the western coast of Africa which terminates in the Bights of Benin and Biafra, of which the form is calculated to favour the operation.

Captain Lawson, who has had opportunities of viewing the coast of *Guinea*, generally, at all seasons, and who has resided occasionally at *Cape Coast Castle*, reports that the level of the sea, in those parts, is higher, by at least six feet perpendicular, in the season of the strong S.W. and southerly winds, which blow obliquely into the Bay of *Benin*, between April and September, (and which is the rainy season,) than during the more serene weather of the opposite season.

The fact is shown by two different circumstances: the one affording a strong presumptive proof; the other, a most positive one. In the former case, that the trunks of trees, which are thrown upon the shore, during the season of the stormy S.W.

winds, are found at the perpendicular height of six to eight feet above the level of the sea, during the other season. And secondly, that during the stormy S.W. season, the tides *ebb* and *flow* regularly, in the several rivers; but, in the other season, the same rivers run *ebb* constantly; the level of the sea being then too low to allow the tide waters to enter the mouths of the rivers.

With respect to the other question, the different effect of the winds, in the Atlantic, at different seasons, on the velocities of the Gulf-stream; it is well known that the seasons produce periodical winds along the whole northern coast of South America; (making a partial monsoon; the great body of the land being all to the southward;) for, when the sun is far advanced into the northern signs, or on its return towards the Equator, the winds blow more directly towards the Caribbean Sea, and are also stronger; and, of course, impel a great volume of water towards it: and it is then, that is, in July, August, and the early part of September, that the Current of Florida is at its *maximum* of velocity. But, when the sun is in the opposite hemisphere, the winds along the coast of the continent, and amongst the larger islands, and the coasts of Florida, have much *northing* in them; and, of course, less water will then be driven towards the West-Indian Seas. And accordingly, it may be seen, by the tables of velocities of the Gulf-stream, (given hereafter,) that the current is commonly less rapid in the season of the northerly winds, which is that season when the sun is far

to the southward[1]. Moreover there is, at that season, a *reflux* of current to the *eastward*, along the coasts of New Granada and Venezuela. The Baron de Humboldt writes, (Vol. iii. p. 378, 9. of his Personal Narrative, English translation,) that, in *autumn*, the wind on the coast of Venezuela, &c. changes from *easterly* to *northerly* or north-west. The currents there, which, during the easterly wind, run to the westward, *cease*, on the arrival of the interval of calm or light winds, between the two periodical ones; and the currents begin to run to the eastward some days before the north-west winds come on. This seems to show that it is the pressure of the wind which keeps up the high level; and that, on the cessation of the former wind, and before the arrival of the other, the water seeks to regain its level. These circumstances must doubtless tend to lower the levels of the Caribbean and Mexican Seas, at this season[2].

To this general statement may be added some particular facts, founded on authorities of consider-

[1] M. Monach, *Cap. de Port* at *Cayenne*, also bears testimony to the increased velocity of the N.W. current, along the coasts of *Brasil* and *Guyana*, between the months of May and October: when he advises the navigators from Europe bound to *Cayenne*, when arrived in latitude 3° N., and longitude $41\frac{2}{3}$° from London, to steer S.W.; which he says is necessary, in order to preserve their parallel; *Cayenne* being in about 5° N. In the other season he says, W.S.W. will suffice.

[2] The same happens in the Bay of Bengal: and doubtless from a like cause. The periodical current changes to the opposite quarter very soon after the cessation of the periodical wind, and long before the opposite wind begins to blow.

able weight, derived from circumstances which took place in March, 1815, and have been already alluded to [1].

In that month, the Gulf-stream was remarked in his Majesty's ships *Gorgon* and *Asia* to be exceedingly rapid, *for the season;* being, by the report on board the Gorgon, 5 miles *per* hour in the narrow part of the Strait of Florida, which is equal to the *maximum* rate of the current in August. Now Captain W. King, of his Majesty's ship *Leonidas*, sailed in the same month from Bermudas to the Equator, and to 2° S. in the direction of Cape St. Roque. He found the trade-wind unusually fresh; and, as he advanced farther south, even *boisterous*; so as to render it prudent to keep away from the wind, although it was his chief object to get as much as possible to windward.

It is proper to remark that the rate of velocity of the Gulf-stream, during the month of March, appears to be extremely various and uncertain. There is a second instance of great velocity, in 1795, when it came up to 97 miles: but in a third, in 1819, it fell to less than one-third of the rate which was remarked in 1815.

Since then the variations in the state of the Gulf-stream are found to accord with the different state of the winds, in respect of their direction and force, can it be supposed otherwise than that the wind alone is the agent which produces the Gulf-

[1] Notwithstanding the above general statements, the "*Derrotero de las Antillas*" has westerly currents along the coast of *Venezuela* in *January*. Perhaps an anomaly.

stream, in the first instance. It certainly appears to the Author that this system accounts, in the most simple and natural way, as well for the high level of the Gulf of Mexico, as for the variations that take place in it.

It has been observed before, that the motion of the waters of the Gulf of Mexico agrees best to the idea of its level being kept up by *pressure*, and not by water supplied by currents. Let the proportions of the *influx* with the *efflux* be compared; and it will then be seen how greatly the latter predominates. And of the proportion of water that flows into it, from the Caribbean Sea, a small proportion only runs to the westward: for one part of it, and that the largest, goes immediately to join the current which runs towards the outlet; and even a part of this latter is returned into the Caribbean Sea, round the Capes of St. Antonio and Corrientes. [*See* Chart V. *of the Florida Strait*, &c.]

Nor does the current of influx advance even so far to the westward as *Vera Cruz*. It may be seen by an inspection of the Chart, that, if a curved line be drawn from *Vera Cruz*, towards the quarter of N.E. by N., so as to pass the parallel of $25\frac{1}{2}^{\circ}$, about the meridian of New Orleans, that line would form, generally, the southern boundary of the *current of the outlet* to that point. From thence, the continuation of that line deviates to the east of south; and afterwards rapidly to the S.E., to the entrance of the Florida Strait; where the curved line terminates.

The western shore of the Gulf of Mexico exhibits most indubitable proofs of the passage of a cur-

rent along it, to the northward, by the long and narrow alluvial islands and mud banks, by which it is bordered, throughout its whole extent: and very similar to those along the south coast of Louisiana and West Florida; along which it is known the continuation of the same current runs. These appearances cannot be mistaken by those who have been in the habit of observing the operation of currents in forming alluvions. And it must be inferred from these appearances, and the circumstances altogether, that the entire surface of that part of the Mexican Sea, or Gulf, within the space between the above said curved line and the western, northern, and eastern, sides of the same sea, is in motion, either circuitously, or *otherwise*, towards the Strait of Florida: and this space may be reckoned equal to three-fifths, or even three-quarters, of the whole expanse of that sea or gulf; and as the volume of water, so discharged, is obviously so vastly greater than that supplied by the current of *inset*, this appears to furnish an additional argument for believing that the level of the Gulf of Mexico can only be regulated, in the first instance, by that of the Caribbean Sea, and remotely by the effect of the trade-wind on the latter.

6.—The FLORIDA or GULF-STREAM. [Chart V.]

General Description of the Stream.

(*Written in the year* 1816.)

The Florida Gulf-stream is well known to issue from the *Gulf* of *Mexico;* whose waters,

acquiring a higher level by accumulation, are discharged with great force and velocity through the channel between the southern Cape of *Florida* and the Island of *Cuba:* and, being subsequently opposed in front by the *Bahama Archipelago*, and its banks and shoals, turns northward, along the coast of *North-America*, skirting it, at no great distance, until it is again opposed by the banks of *Nantucket* and *St. George*, which advance far into the ocean, from the shores of *New York* and *New England*. These turn it so decidedly from the coast[1], that it never again returns to it; but perseveres in its newly acquired eastwardly course, through the *Atlantic*, passing over, or near, the tail of the *Great Bank* of *Newfoundland*, and to a point several degrees beyond it; when the stream from the *Hudson's* and *Davis's Straits appears* to give it a cast to the south-eastward. At this point, although it has made a course of more than 2,000 nautic miles, it still preserves a velocity of one mile and a quarter *per* hour; as also a temperature of 7 to 10 degrees of Fahrenheit's thermometer above the *summer temperature* of the surrounding ocean.

So vast a body of water, making its way through the ocean, and carrying a breadth of 100 to 200

[1] One can conclude only, from analogy, that this sudden change in the course is produced by the opposition of the *Banks* of *Nantucket* and *St. George:* since a perfectly similar case happens in the current off the *Cape* of *Good Hope*, which is suddenly turned from a *westerly* to a *southerly* course, by the opposition of the bank of *Lagullas*.

miles after its *expansion*, and with a velocity of two to $4\frac{1}{2}$ miles per hour, cannot but materially affect the course of navigation. It moreover affects it in another way; for, preserving a great proportion of the warmth which it acquired in the torrid zone, it influences the weather, by communicating its warmth to the incumbent atmosphere[1]. It then becomes naturally an object of inquiry, whether the position of its borders, its *general* lines of direction, as also that of the *most rapid* part of it, be sufficiently known; in order to aid, in the most effectual manner, the purposes of navigation, by instructing navigators how to turn it to the most

[1] That the temperature of the atmosphere is affected by very wide streams of current, whether warmer or colder than the adjacent sea, is very certain; the Gulf-stream rendering it warmer; the Equatorial stream, and some others, cooler. If the temperature of the Mexican Sea be taken at 86° in summer, the Gulf-stream loses only five degrees in running about 1,300 miles to the north-eastward.

The temperatures in the chart are all taken at the height of summer (Sir Charles Blagden's excepted.) In winter the disparity is much greater.

Besides the effect that may be expected to be produced by the stream itself, the vast deposit of warmer water on the west and S.W. of the *Azores*, must also affect a vast tract of atmosphere. Is it too much then to suppose that these operations on the atmosphere produce the frequent storms near the *Azores;* particularly in winter, when the contrast is the greatest? It is confidently said, that the storms are seldom, if ever, felt on the south of the parallel of 35°: as also, that the cautious old people kept to the southward of 35°, on their return from the West-Indies, to avoid them.

advantage, when favourable to their course; and how to avoid it, when adverse.

Another head of inquiry connected with it, and no less important to navigation, is the *setting* of the COUNTER CURRENTS, which prevail, more or less, and often in great strength, beyond the borders of the *direct* stream; and owing their existence to it, as is common with currents in general. It is on record, that a squadron which sailed from *Bermudas* towards the stream, was set, in 24 hours, 90 miles to the southward.

Its general course, as far as respects the ordinary navigation of merchant ships from the *West-Indies* towards *Europe*, is, perhaps, sufficiently understood, within the space to which their ordinary routes are confined; that is, between the *Bahama Islands* and *Cape Hatteras;* for as, throughout this space, the stream runs parallel to the general line of the coast, passing at no great distance from it, this bearing, together with the latitudes, sufficiently marks its course and velocity. But to the north of *Cape Hatteras*, as a tract lying beyond the route of those ships, the inner border of the stream, from want of those long continued observations, is but imperfectly known, and has been erroneously described in the charts and books of directions. So that there is a deficiency in the hydrography of the most important part of the stream, as it respects the motions and stations of our national fleets. This has been manifested by the observations made by Captain Pell, of his

Majesty's ship *Menai*, and which have been most obligingly communicated to me by Captain Hurd[1], who has been pleased, on every occasion, to forward my work on the currents of the ocean.

These observations prove, to a certainty, that, between the parallel of *Cape Hatteras* (35°) and 38°, the existing charts are erroneous: for, according to these, *the body of the Gulf-stream* shoots off from Cape *Hatteras*, in a north-easterly direction, so as to leave a great space of *still water* in the offings of the *Chesapeake* and *Delaware;* whereas, according to Captain Pell, the *inner* border of the stream approaches those shores, much in the same manner as it does those of *Carolina* and *Georgia:* at the same time that the *outer* or eastern border, together with the main part of the stream itself, sets generally to the *east*, carrying ships *directly* to *sea-ward:* so that with north-west winds, which are so frequent and boisterous, some of his Majesty's ships have been kept six weeks off their stations.

I conclude that the *continuation* of the *strength* of the Gulf-stream, so far to the eastward, as is now shown by the observations of Captain Pell, and those of Captain Beaufort, was a circumstance not so well known[2]. Here it is in proof that it runs at the rate of two miles per hour, at 160

[1] The late respected Captain Thomas Hurd, R.N., Hydrographer to the Admiralty.—Ed.

[2] The observations of Captain Rodd, of H. M. S. Warrior, on his return from Jamaica (1815), equally prove the great extension of the Gulf-stream eastward.

leagues to the eastward of the *Delaware;* and that even at more than two-thirds of the distance across the ocean, towards the *Azores*, at the rate of one mile and a quarter per hour. This latter particular is corroborated by the water of the stream having lost so little of its warmth: it being still from 7 to 10 degrees warmer than the *summer heat* of the adjacent sea, although it has ran considerably more than 2,000 nautic miles from the Strait of Florida.

It then becomes a matter of consideration how, in arranging the line of a passage from Europe to the Northern States of America, the adverse current of the Gulf-stream is to be avoided? I conclude that, in the present state of our knowledge, no one can say where the *borders* of this stream are: so that it is possible that a ship may have the current against her during nearly one-half of the passage!

That the extended course, and great velocity of this easterly current, should have been so little known, is easily accounted for. The detection of errors in the longitude could be effected only by the use of chronometers and lunar observations; and very few of the ships that pass in this track have possessed the means; whilst the errors in the other part of the stream were easily known by the differences of latitude, and the general direction of the sea coast. It must also be taken into the account, that improvements in hydrography depend, at all times, on the industry of a few meritorious individuals; and whose observations, from their

want of connexion with each other, often fail to accomplish the desired purpose.

Mr. Murdo Downie, master of his Majesty's ship *Resolution*, in 1798, has particularly dwelt on the existence and effect of the eastwardly current, and has given a caution to navigators, who are bound to the westward, accordingly. He had experienced it as far to the south as latitude 36°, in the meridian of 66° west longitude, where it ran at the rate of one mile and a half per hour.

CONCERNING *the mode of* SURVEYING *the* GULF-STREAM; it naturally occurs that the vessel, so employed, would *zig-zag* across it, at proper intervals of space, occasionally making the land, in order to check the chronometers, and stand outwards, far enough to ascertain the main direction of the counter currents. As the temperature of the water of the stream, compared with that of the ocean at large, proves a most useful guide to the common navigation of this stream, these particulars would also be attended to, as well as the particular direction of the stream and its velocity, in different parts of it. The greatest velocity, as well as the greatest degree of warmth, appears to be rather towards the left hand, or western side, than in the middle: one probably depends on the other. Attention should also be paid to the position and disposition of the gulf-weed; and how far, if possible, it may be made a criterion, either of the presence of the stream at large, or of the line of the strongest part of the current. As also, by

raising the water from below, how deep the bed of the stream may be. This examination will also furnish a means of judging what effect the stream has on the weather, by warming the incumbent atmosphere.

Bottles thrown out from time to time, in the strongest line of current, may lead to some useful results.

It is very commonly asserted, that very strong winds, which blow *across* the Gulf-stream, in its way along the American coast, force the main body of the stream nearer to the shore, in one case, and farther off in the other. It is difficult to believe that such a body can be moved by the wind; but it is very probable that in the one case, it forces the *edge of the stream* over the adjacent sea; and, in the other, the edge of the sea over the stream; which would, in either case, produce the same appearance, on the surface, as if the body of the stream was moved. This might easily be ascertained by drawing up some of the water from below, at such seasons.

A MORE PARTICULAR DESCRIPTION OF THE GULF-STREAM IN GENERAL. [CHART V.]

(*Written in and subsequent to* 1821.)

THE GULF-STREAM, or discharge of the accumulated waters of the Mexican and Caribbean Seas, is, no doubt, the most remarkable of any known; whether in point of velocity, or the extent of course to which its waters are projected, and discovered

by their warm temperature. They have been detected in the Bay of Biscay, 4200 miles distant from the sea of Mexico; and at all times reach the Azores; more than 3000 miles.

I regard the *western part* of the Caribbean Sea, and the *Mexican sea at large*, as being nearly on a *par*, in point of level. The constant discharge of the water through the Strait of Florida (that is, the *Gulf-stream*), must, of course, produce a correspondent motion of the water from the *Caribbean* to the *Mexican* Sea, through the channel of *Yucatan*, between the extreme point of Yucatan and the west end of Cuba. This current makes the tour of the *eastern* part of the *Sea* (or *Gulf*, as it is *improperly called*,) of Mexico; and finally forms what is properly the head or commencement of the Gulf-stream, between the northern shore of Cuba and the Florida Reefs; first taking an easterly direction, past the city of Havanna, and then, winding round, with a great sweep, to the N.E. and north, through the Strait of Florida, formed by the eastern side of Florida and the opposite islands and reefs of the Bahamas. The narrowest part of this strait is situated at about 67 leagues to the north-eastward of the Havanna, and the *water-way* is there only 36 miles in breadth, having been narrowed to that space, from a breadth of about 70 miles, opposite the Havanna; and it afterwards expands to 50, before it quits the strait[1].

[1] The navigation through this strait is a matter of some delicacy. The place where the most shipwrecks happen is between

Previously to its arrival at the *Narrows*, the velocity of the current is much less than afterwards,

the *Narrows*, formed by Cape Florida and the Bemini Isles and the *Great Inlet*, at about 15 leagues higher up, on the Florida side. A long narrow shoal extends along, parallel to the Florida coast, forming a narrow channel within, called the *Hawke;* through which small vessels pass to the southward, with the advantage of a southerly or *counter current*. The Hawke Channel terminates at Cape Florida, where the counter current commences; and, at 15 leagues farther to the southward the channel called the *Great Inlet* occurs. This inlet forms a clear communication between the Florida or Gulf-stream and the Hawke Channel; into which a current sets, with some rapidity, from the main stream. Of course, the *flowing out* of both those derivations, will disturb the regularity of the main stream in the part towards the Florida side; and will put those who keep on that side during the night, and are not aware of the circumstance, into great danger, by drawing them towards the Inlet, or the opening at Cape Florida, as it may happen. His Majesty's ship *Larne* was carried into the former during the night, but escaped wreck. The latitude of the Inlet, taken on board the *Larne*, was 24° 54′ N.

The *Salt Kays*, or Double-headed Shot, form the proper *point of departure* for the strait. The position of this point, in respect of the ship, ought to be fully known, before any one ventures in the night time into the entrance of the strait; as, also, some general idea of the rate of the existing current, should previously be known.

It may be observed that, in navigating this part of the Gulf-stream, during the night, the temperature of the water will afford great assistance toward ascertaining the position of the ship, in respect to the middle of the stream. The water is warmest in the middle, and gradually cooler towards the sides of the stream. It would be better not to keep in the middle, because, on the water growing cooler, it might not be so certainly known towards which side it was; but if the ship were first placed on either side, in a temperature corresponding with a moderate distance from the middle, the danger of a mistake would be greatly lessened.

which shows how greatthe effect of this compression is, towards producing such a length of course.

The stream has its greatest velocity in the months of July, August, and part of September; for then it is that the easterly winds are strongest, and of course force more water into the reservoir. The *maximum* of velocity at the *Narrows*, in July and August, was respectively 96 and 120 miles in the twenty-four hours. The *mean* rate *above* the Narrows in those months, collectively, 44; *below*, 100; and, from the *opening* of the *Strait* into the Atlantic, to lat. 31° (that is, 180 miles), the mean was 82; and finally, it is very commonly at 48 miles, or two knots an hour, on a line extending from Bermudas to Halifax; that is, after it has ran upwards of 1100 miles. But it must not be supposed that any regularity takes place; on the contrary, it is very uncertain; and seems to depend on the cause, whatsoever it be, which determines the levels of the reservoir.

The stream, having received a due north direction from being so long confined within a channel lying in that direction, continues it till turned aside by a new cause. This is the coast of Georgia, which, bending to the north-eastward, from about the parallel of $31\frac{1}{2}°$, or 32°, naturally compels the stream to turn to the N.E. also, after it has run on a straight northerly course six degrees of latitude, or 360 miles beyond the Narrows of the Strait of Florida. The well known effect of the expansion of streams of water, as they advance, takes place here: from being 50 miles broad

at its *outlet*, it is said to be about 60 to 63, after it has turned to the N.E., and passes opposite to *Charlestown;* and, opposite Cape Hatteras, situated at about 300 miles beyond the turning off, about 75. Thus, in a course of less than 550 miles, it expands one half of its original breadth.

Its exact course from the turning to Cape Hatteras, is N.E. $\frac{1}{2}$ E., or E. 40° N. Its inner edge is reported by the Americans to be twenty-four miles to the S.E. of the Cape, and in 60 fathoms depth of water. But the dangerous shoals that extend from the Cape, are only 12 miles within the edge of the stream. In this part of the stream, Captain Livingston found the rate of motion to be 68 miles in the twenty-four hours, in *August;* and the rate is generally understood to be from 3 to $2\frac{3}{4}$ knots between the *outfall* and *Cape Hatteras*, in latitude 35° and a few minutes. All this is meant to refer to the mean rate.

The temperature of the stream will, perhaps, be better spoken of, after its general course has been described. I shall only mention, in this place, that it loses only three degrees of its warmth in the course of the first 900 miles; taking 86° for the Sea of Mexico.

At Cape Hatteras, the coast falls back suddenly from the N.E. to the *westward* of north. The western border of the stream being now freed from the restraint imposed on it by the land, expands on that side, and takes a more northerly direction, whilst the main body continues its former course to a considerable distance. But, meeting the Nan-

tucket and St. George's banks, it is turned off to *seaward*, and never afterwards approaches any land. When first turned off, the central part of the stream takes a direct eastwardly course, and finally to the southward of east, at the same time expanding to a vast breadth[1]. At the distance of about 300 miles from the edge of the bank of soundings, opposite to the entrance of the Chesapeake, (in lat. 37°, long. 68½,) it regains a part of its northerly direction; that is, between the E. by N. and E.N.E., but is still full two points more easterly than its former course along the edges of the banks of the Carolinas. On this line of course, then, we trace a *thread of current* of considerable, but gradually diminishing, force and warmth, through about 1200 miles of the Atlantic Ocean, or to a point nearly midway between the Chesapeake and Cape Finisterre, (lat. 42½°, long. 43¼°.)[2] Here it begins to bend to the east and S.E. and finally to south, till it passes by the west side of the *Azores*, a course of nearly 600 miles farther; completing a course of more than 3000 miles from the Gulf of Mexico. This appears to be its usual term; but, in the year 1776, its warm water was traced into the Bay of Biscay, and nearly, or perhaps home, to the French coast; regularly decreasing in temperature. At all other times, ships have found the

[1] There is no portion of the Gulf-stream less known, and which ought to be *better known*, than that between Cape Hatteras and the banks of New York and St. George.

[2] It may be observed that the Bay of Biscay lies in the same direction as that line of the 1200 miles across the Atlantic.

water of *ocean temperature* in their passages southward, between the Azores and the continent. When the Gulf-water nearly reached the old continent, its length of course was upwards of 4200 geographic miles.

The breadth of the Gulf-stream, beyond Cape Hatteras, appears to vary exceedingly; and, as simultaneous experiments have, in very few instances, been made, at its limits to the north and south, nothing determinate can be offered. It may, also, be supposed, from experiments, and more especially from the reports of the American navigators, that it *varies in its course*, in respect of parallel. But this is certain, that, in latitude 39° 50′, long. 62° 40′, a rate of 48 miles, or two knots per hour, E. 18° N., with a temperature of 81° in August *(maximum)* was found: and again, in lat. 44°, long. 45°, a rate of 30 and 31 miles, E. 18° N., with a temperature of 76° in August. Also that, on the opposite or southern side of the stream, rates of 32 and 35 miles were found in September in a *different* year, in latitude 40° 30′: so that, if this were to be taken for the general state of things, the stream would be no less than 220 miles in breadth in this place. But this may admit of great doubt, although a second and competent authority (but in a different year from either of the former) found, in latitude 39° 30′, long. 50°, a rate of 45 miles in September, with a temperature of 77°: and, in the same spot and season, the former authority gives 44 miles.

I think it not at all improbable that the stream

may be 150 miles broad in the line between Bermudas and Halifax ; that is, in long. of about $63\frac{1}{2}^{\circ}$; and that, in longitude 50°, it may be 180 miles or more. Captain Pell, in H. M. S. Menai, who made the observations in 39° $50'$ N. and $63\frac{1}{2}^{\circ}$ W., estimated its breadth, in that part, at 141 miles.

Although examples of the breadth of the stream are wanting, yet there are several of the breadth of the *warm* water between the longitudes of 63° and 67°. But the presence of warm water is no *proof* of a *current;* since the stream is known to deposit its waters, not only at and near its termination, but during a great part of its course through the middle of the Atlantic. This has given rise to very erroneous statements concerning the extent of the stream ; it having been taken for granted, that all the warm water formed a part of the stream itself; although, on the contrary, it may be only stagnant water, or part of a *counter current* returning to the westward.

The following are the statements of the extent of warm water :—

In H. M. S. *Newcastle*, in *February*, 1820, Mr. James Napier, master, found the warm water to extend from latitude 37° $20'$ to 39° $40'$; that is, a breadth of only 140 miles : but, in *May*, in the same year, it extended from 35° $20'$ to 40° $33'$; giving a breadth of 300 miles of warm water.

The *Opossum*, in June, 1817, found warm water only between lat. 36° $55'$ and 39° $21'$; that is, a breadth of 146 miles, or almost exactly the same as the Newcastle, in February.

The *Maidstone*, in the month of June, found warm water between the parallels of 35° 20′ and 39° 30′, or a breadth of 250 miles.

In the *Menai*, Captain Pell, above cited, the breadth of the current was taken at 140 to 150 miles; but, by circumstances, it appears probable, that the breadth of the *warm water* was 160 or 170; and that it extended northward beyond latitude 40°.

As the whole distance between the tracks of the Maidstone and Newcastle, including that of the Opossum, at their northern termination, does not exceed 135 miles; and the extreme difference of latitude between them only 72 minutes; the results, taken as points, in the northern border of the warm water, will be found to differ but little, in bearing, from the direction of the stream above given, between E. by N. and E.N.E.; or, more correctly, about E. 18° N.

Dr. Franklin states that the Nantucket whale fishers place the edge of the Gulf-water in latitude 41½°, in the meridian of Sable Island, or about 60° W.[1] As the whales avoid the warm water, the fishers probably were correct. It carries the warm water somewhat higher than the former statement. But there is a very consistent account of there being warm water as high as latitude 42¼° in the same longitude; and also of *very warm* water at 50 miles to the northward of the Maidstone's

[1] Colonel Jonathan Williams describes the northern edge of the stream, to reach to lat. 41° 57′ in the meridian of 65° west; and that *whirlpools*, on its supposed border, have been seen in 42°.

position, when she entered the warm water from the northward, as shown hereafter.

There can be no doubt then, that, at least, the *extent* of the warm water varies on the north side of the stream.

On the southward, there seems little reason to doubt but that the warm water, in general, extends to latitude 35°, even from longitude 60° *westward;* and, eastward of that meridian, it seems to extend to 34°, or more southwardly. For, at the usual termination of the Gulf-stream, on the S.W. and west of the Azores, it deposits its warm water; a part of which returns to the westward in form of a *counter current,* or spreads to the S.W. All which is apparent from journals, particularly those of Dr. Franklin himself.

Dr. Franklin found a set of four degrees of longitude to the *westward*, keeping near the parallel of 35°, between longitude 40° W. and the coast of America, in a temperature from four to eight degrees above that of the ocean, and most commonly 7°. The counter current continues along the eastern border of the Gulf-stream, even to the opening of the Strait of *Florida;* where, joined by the *drift water* of the N.E. trade-wind, it is turned to the S.E., ranging along the north of the *Bahamas*, &c.

Since then the presence of warm water is no proof of being in the Gulf-*stream*, it will be for ever difficult, if not impracticable, to fix the extent of that stream on the chart by *casual* observations. It can be done only by *repeated* observa-

tions of latitude, taken at no great distance of parallel from each other; and this requires the use of a vessel or vessels, specially employed for the purpose, and for more than one season. If it were done at certain points of the Stream only, that might suffice; and those points would, of course, be chosen, which lay in the usual crossing places, as, for instance, opposite to the *Chesapeake*, *New York*, *Boston*, *Halifax*, &c.

The limits of the counter currents are equally important to navigation. Could it have been believed that such points of hydrography were neglected after chronometers had been forty to fifty years in use? That ships should be allowed to blunder and *grope* their way across the Atlantic, unknowing whether they were in an easterly or westerly current, until the termination of their voyages?

The most important particular known is, that, in the line between a station about 100 leagues to the eastward of the Chesapeake, and another situated in about latitude $42\frac{1}{2}^0$, long. $43\frac{1}{4}^0$, as already shown (page 163), there is a *thread* of current in a direction of about E. by N. $\frac{1}{2}$ N., and which may be supposed to extend to a considerable breadth on each side of that line.

The velocity and temperature of the Gulf-stream, from its origin to Cape Hatteras, has been already mentioned (page 162); the former 68 miles in the 24 hours; the latter 3^0 less than at the head; or 83^0 in September, when at, or near, its *maximum*.

After receiving a check from the banks, by

which it is *turned* off from the coast of Virginia to the eastward, its velocity (as happens in all streams after being impeded, by which their levels are temporarily raised), was found by Captain Pell to be increased to 95 miles, or nearly four knots per hour. After it has recovered its course to the northward of east, Captains Rodd and Pell found 48 to 66 miles, through a space of nearly twelve degrees of longitude, between the parallels of about $37\frac{1}{2}°$ and $40°$. Then follows a blank through $12\frac{1}{2}$ degrees of longitude in the former direction[1]; and then we arrive at the examples cited in page 164, at the end of the long line of 1200 miles, where 30 and 31 miles were noted, on the *same bearing*, as the intermediate examples. So that there appears to be a pretty regular decrease of velocity through this space.

The temperatures observed were in July, August, and September, including about two months, which was nearly the season when the ocean, in that quarter, is at its *maximum* of temperature; the Gulf-water must also have left its place much in the same state. From being 83° at Hatteras, it gradually decreased to 76° at the end of 1200 miles.

After it begins to bend towards the east, and

[1] It is probable that there would not have been any blank there, in that thread of current, but for the accident of Captain Rodd's being driven out of the stream (which he was in the act of tracing) by a furious hurricane in latitude $40\frac{1}{2}°$, longitude $60°$. He did not regain the stream again till he arrived in longitude 45°, as noticed in the sequel.

thence to S.E. and south, its velocity diminishes more rapidly; but not so its temperature: for in its course of nearly 600 miles, to the neighbourhood of the Azores, its temperature diminishes only two degrees; that is, from 76° to 74°, whilst the rate of motion is diminished to ten miles, or lessened more than 20, in the course of 600 miles. At this point (*Corvo*) I have considered the stream to end, because the differences between the ship's reckonings and the celestial observations are too small to detect a current; but doubtless the Gulf-water moves farther on, and this seems proved by the higher temperature of the sea, on the S.W. of the great body of the Azores; that is, 200 or 250 miles beyond *Corvo*, where the temperature is reduced to 73° and 72°.

The vast mass of warm water, brought by the Gulf-stream in such rapid succession through the Atlantic, cannot but form a kind of vast lake of water, whose temperature is, at all times, much *higher* than that of the surrounding ocean [1]. This temperature it, of course, communicates to the incumbent atmosphere; so that it is productive of the most violent and frequent gales of wind. It is even satisfactorily ascertained, by an examination ordered by the Admiralty, that the great and oftentimes fatal storms in the North-Atlantic, that have

[1] Sir Philip Broke experienced an atmosphere of 81 degrees of temperature in latitude 39° and upwards in November. The muggy state of the atmosphere destroyed the use of his chronometers in six weeks. The *Harmattan* wind, (hot and dry) on the Guinea coast, is said to produce the like effect.

happened in the course of the last thirty or forty years, have been within, or on the borders of, this recipient of the Gulf-water, but chiefly on its borders [1].

The deposited water, from some reason or other, is mostly found on the south and S.E. sides.

We now turn again to the WESTWARD, *towards the* DELAWARE, in order to give some remarks made on the western and north-western borders of the stream.

Captain W. Billings, of Philadelphia, in the beginning of September, 1792, found a temperature of 74° and 75°, (6° or 7° above ocean temperature,) in latitude 39°, at 25 leagues only to the eastward of the entrance of the Delaware: and, in the preceding June, in 37½° N., he found 70°, or 5° above ocean temperature, at a few leagues farther off shore. The place of the former of these observations bears from the inner edge of the Gulf-

[1] I should not omit to mention that, in October, 1817, a journal kept in H. M. S. Port-Royal, gives a temperature of 80°, 84°, and 85°, in Funchal Road, Madeira; and between that and latitude 29° 55′, in the line towards *Palma*, 88° in 31° 38′; 84° in 29° 55′; and off Palma itself 72½°, the same as they had experienced in 32° 41′, before anchoring at Funchal. This is worth a second experiment. It is justly remarked, I believe, that the *whole base* of the cluster of the Canary Islands is likely to be *volcanic*. I conceive 72° or 72½° to be the ocean temperature at that season in the parallel of Madeira.

The Baron Alex. de Humboldt's temperatures across the Atlantic, &c., as reduced from his table of comparison between the centesimal thermometer and that of Fahrenheit, are all much lower than any other person's. I suspect some error.

stream off Cape Hatteras, in the same line of direction (N.N.E.) with that of the observations of Captain Pell, *midway between the two;* where *very warm* water and a strong north-easterly current were found.

But the report of Mr. Downie appears positive in respect of the approach of the Gulf-stream to St. George's Bank.

Mr. Murdo Downie, formerly master of H. M. ship *Resolution*, after five years' experience, whilst on the American coast, appears to prove, satisfactorily, the fact of the stream coming up to the northward, to the edges of the banks of *Nantucket* and *St. George*. His words will be found in the accompanying note; by which it seems clear that east and E.S.E. winds force the surface water of the edge of the Gulf-stream close to, or even upon, the edges of those banks: and that, when westerly or north-west winds blow, it is removed to some leagues' distance only from them [1].

[1] "I found that, with east and south-east winds, the current is forced close to, and in places, upon, the edge of soundings; when, being confined or pent in between the east wind and the shoal-water near the shore, its breadth is then greatly diminished, but its velocity is increased in proportion.

"The places where I had an opportunity of observing this to prevail, were *from about the longitude of Block Island* (71° 43′) *along the edge of the Nantucket Bank, until past St. George's Bank;* and again, along the coast of Georgia and part of South Carolina. *In the first place, I observed the southerly winds force the current close to the edge of soundings, where it would then run from* $1\frac{1}{2}$ *to 2 knots;* and, in the latter place, I found the easterly wind forced the current upon soundings. When the west and

On an attentive consideration of the shape of the recess formed by these banks, together with that of the corresponding bend of the stream, where it so suddenly turns off from the coast, one can no other way account for the change, than from *some obstacle in front;* and which may reasonably be concluded to be no other than the aforesaid banks.

We are fully aware that every person is not prepared to believe that a stream of current *can* be turned aside, by banks 40 or more fathoms under water. But it is an unquestionable fact, that the Stream of *Lagullas* is turned aside by a bank at a very much greater depth[1]. Who can form any rule for judging the depth of a stream of 60 or 100 miles in breadth? It may be supposed that, at the outlet of the Florida Strait, the stream occupies the whole depth of the passage; and which is, no

north-west winds blew, the inner edge of the stream would be removed some leagues farther off; so that, from these circumstances, the situation of the eddies caused by the stream, must be very uncertain indeed."

[1] The body of the Lagullas Stream is turned aside by the edge of the bank, although the depths be from 90 to 100 fathoms. Nor does this fact rest alone on the examples of the *setting* of the current: for it is also proved by the thermometer. The current coming from a warmer region, like the Gulf-stream, is many degrees warmer than the Ocean-water at the bank. Dr. Davy experienced a difference of 10 or 11 degrees between the bank and the stream, in June: and Captain Alsagar, in one instance, in the distance of about a mile and a half, 10 degrees, in March; and in another instance, $7\frac{1}{2}$, in the course of a few miles.

The Lagullas Bank, in the part where the stream strikes it, and the body of which is thence turned aside, goes down almost perpendicularly to 255 and 258 fathoms.

doubt, *worn down* to a vast depth by the force of a stream of three to five miles *per* hour, which has been *pouring down* for ages [1]?

The *exceeding steepness* of the edge of the bank, in the part where the current is supposed to strike, and afterwards turns off from the shore, is a circumstance not to be overlooked in this inquiry. For the edges of these banks are so steep, that the bottom near them is not reached with 100 fathoms of line. Now this steepness is a quality in the supposed obstacle, likely to give a sudden and violent check to the body of the stream; and, in consequence, to give it a new direction.

The *increased velocity* of the stream, after its being thrown off the shore, is also in favour of our supposition; for it increases from $2\frac{1}{2}$, under its former course, to 4 miles *per* hour, after it has taken an easterly and E.S.E. course. But after this, it regains, with its *east-northerly* course, what may be termed its *natural* rate of motion [2].

This appears to indicate its having been in the act of surmounting an impediment, and afterwards of recovering the effect of the impression. For when streams of current, whether in a sea or river, meet with obstacles sufficient to impede their rate

[1] Let it only be considered what pits or holes are formed by the descent of water at locks in a river.

[2] The Nantucket masters allow 60 or 70 miles *per* day, for the rate of motion of the stream, "*after it has turned eastward.*" As they say "*generally,*" one may conclude that it is to be taken as the *mean* velocity. *Our* mean, within the same space, is rather lower.

of motion for a time, an accumulation of *back water* necessarily takes place; and which, afterwards pressing with additional force, to restore the *equilibrium*, quickens the motion of the stream for a time.

If we extend our view from the Nantucket and St. George's Banks, to the north-eastward, along the continuation of the chain of banks, of which the two former make a part, it will be found that a great degree of steepness of their edges will be found to take place; that is, from 60 and 80 fathoms on the edges to 150 and 300, without reaching the bottom. And this continues as far as lat. 45°, in the meridians of Newfoundland. The Author suspects that this has been owing to the operation of the Gulf-stream at some former period; or, as we know so little in detail of this part, it may be, that the northern edge of the stream, occasionally, comes up so high now: and Colonel Williams's *whirlpools*, in latitude 42°, and long. 65°, were at the edge of the bank. Moreover, the nature of the banks, in respect of their declivity, and the proximity of the current to them, being much the same from *Georgia* to *New England*, one may suspect that the whole chain of banks owes its declivity to the same cause.

It may well be a question also, what occasions a stream to pursue its course along-shore so much farther at one time than at another? But here, indeed, there appears to be less difficulty. It is well known that the velocity of the stream is, at times, nearly double as much as at others; and

that the season when rapid currents most commonly prevail, in the Strait of Florida, is in the summer months. It was in August and September that Captain Pell experienced rapid currents opposite the Chesapeake, and so much farther to the northward than where Mr. Napier found a weak current in April. The difference of velocity may possibly account for this, or for the projection of the stream farther to the northward, and to the bank of St. George, before it turns off from the coast of America. But the cause of its turning off *at all*, under ordinary circumstances, remains a *desideratum*.

It appears that the known variations in the breadth of the warm water in the quarter where the Gulf-stream turns off from the American shore, between latitudes 34° and 39°, are about 300 miles from north to south, but the breadth of the part *in motion*, that is, the existing Gulf-stream, does not at any time exceed 120 miles, and is probably oftentimes much less.

It was the practice of former times for ships from the West-Indies to keep to the southward of the parallel of 33°; and it was even an acknowledged fact, sixty to seventy years ago, that the great storms happened to the north of 32° or 33°. How then could this fact be so far forgotten, as that it has been recognized as a *new* one, and ordered to be acted on, as I am informed, in these times. It is allowed by the most experienced navigators, that, although the favourable current of the Gulf-stream may save a merchant-ship a distance equal

to four days' sail, yet that not only the hazard incurred from weather overbalances the convenience, but that ships come by the southern passage in equal times.

On the PASSAGES from the WEST INDIES, as affected by the Gulf-stream.

Notwithstanding, therefore, the advantages to be gained, in point of distance, by ships returning from the West-Indies by the favouring current of the Gulf-stream, which may be perhaps reckoned equal to several days' ordinary sailing; yet experienced navigators are still of opinion that, on the whole, it does not present equal advantages with the southern route.

For, it is alleged that, in following the course of the Gulf-stream during its range along, or parallel to, the coast of America, and afterwards during its course across the Atlantic, they are obnoxious to the violent storms that often prevail there throughout its whole extent; particularly from the north-west winds from the continent of America; by all which great damage in wear and tear is incurred; and delay is created, instead of gaining time, notwithstanding the help derived from the *Stream*. In effect, that they navigate nearly the *whole* breadth of the Atlantic through stormy latitudes, when they need only to navigate one-third of it in that mode.

It is also agreed, that the Gulf-stream itself, in *winter*, ought to be particularly avoided, as having

a heavy and irregular wave, which occasions ships to labour much; and must, therefore, be very hurtful to deep-laden vessels.

It was, until latter times, held as a maxim, not to come to the northward of the parallel of 33°, in returning from the West-Indies, because of the prevalence of storms to the northward of it. This wise rule of our ancestors has been, in general, most unaccountably disregarded, or absolutely forgotten; yet it was impressed on my mind upon this spot, when a youth, upwards of sixty years ago, and consequently not forgotten by me. The loss of ships and lives, has, in consequence, been very great. Within these few years the rule has been again taken up, and his Majesty's ships, and of course convoys, will be, in future, directed to proceed by the south of Bermudas, and to cross its parallel a few degrees to the eastward of it, and thence to steer direct for Corvo.

The Lords of the Admiralty, a few years ago, set on foot an inquiry by which it appeared that the heavy and disastrous gales of wind that had happened in the Atlantic, in latter times, arose probably from the influence of the warm water of the Gulf-stream; and that nearly, if not the whole, of those to the west of the meridian of the Azores, happened either within or on the verge of the expanse of Gulf-water; (as may be seen by the chart on which they are particularized;) and those east of the Azores were in and about the line taken by the Gulf-water in 1776.

The southern boundary of the tract in which

these gales happened is actually on the parallel of 33°, one instance excepted, that is, at the outfall of the Gulf-stream itself.

It may be observed, that a track which should cross the parallel of Bermudas, at a very few degrees to the eastward of it, and then lead directly towards Corvo, would cross a most critical portion of the space in which, not only the warm water of the Gulf-stream prevailed, but in which several gales are actually reported in the Admiralty paper before mentioned. Therefore, it would seem, that the parallel of Bermudas should not be crossed at less than about fifteen degrees to the eastward of the islands. Sir Philip Durham, it appears, crossed it at ten degrees.

But, it may be asked, where is the necessity of going to Corvo or Flores at all, for by it ships are placed in a situation proverbially known as a place of storms; that is to say, on the west and N.W. of the Azores: why not go between *them* and the *Greater Azores*; or, rather to the southward of them all, and thereby pass through a kindlier climate at all times?

The *Region of Storms* is more properly *that* which commences at the place where the Gulf-stream leaves the coast of America, and forms the wide expanse of warm water before described. Therefore, in order to avoid the stormy parallels, it is not necessary that ships should avoid the Strait of Florida altogether, and attempt the Windward Passages. At certain seasons *these* could not be attempted by loaded merchant-ships; but they

may pass the Strait, and take the advantage of the Gulf-stream, to get out of the trade-wind; and here it is that the Gulf-stream is of the most service to navigators; and, having cleared the trade-wind, which seldom reaches to latitude 28½°, they may then sail to the eastward, avoiding the stormy parallels.

Any calculation or comparisons of time in making the different passages would be nugatory; since the security of lives and property is the main object; but it even happens that ships, which have had all the advantage of the Gulf-stream, have been crippled, and made more delay than in the southern passage, with adverse currents.

Descriptions of the Gulf-stream may be found in the directories for the navigation of it; but there are certain particulars in them, in which persons of the highest respectability do not agree.

As Sir Philip Broke's description is the only one that the Author has seen of the state of it in winter, and far into the Atlantic, it is here subjoined.

"During six weeks in October and November, 1811; three weeks within its influence, either crossing it between the parallels of 38° 30′ and 40° 30′, and longitude 60° to 63° by *observation*. Mostly continued blowing weather from N.W., S.W., or south. The current, irregular in velocity, but constantly to the E.S.E.: never less than 25 or 30 miles, and several times 50, in the twenty-four hours: always seen by *gulf-weed*.

"My chronometer was, at first, very correct, as we had opportunities of ascertaining by *lunar* observations: but I soon found, both from our own observations and the report of my brother officers, that the best chronometers became irregular in the *heavy warm damp air* over the stream; the thermometer standing at summer heat, and once at 80°, whilst it stood near the *freezing* point beyond its borders, as well to the south as the north.

"When the wind opposed the current, the sea was always heavy and broken, so as to occasion the ship to labour much under any trim of sail whatever."

These observations were confirmed in after cruises.

Sir Philip adds, "Those who have no reason for navigating in this stream, should always avoid it in the winter season; as the sea which prevails there is unusually heavy and irregular[1]."

[1] *Remarks by Sir Philip Broke,* 1811, 1813.—"The climate where it prevails is noted for warm, squally, wet, unsettled weather; and in S.W. or west gales the air is sultry hot, even in the winter; and, in the latitudes of 39° and 40°, when just beyond its influence, the weather is extremely cold.

"Between the latitudes of 38° and 40°, longitudes 56° and 64°, I have known cruisers thrown out of their reckoning nine degrees of longitude in ten or eleven days, by this current. Upon just quitting its limits to the northward, between 60° and 65° W., ships are frequently affected by a strong counter current, to the N.W. from 20 to 40 miles in the 24 hours; but this is a very irregular eddy, and not always prevailing.

"Without the southern border of the Gulf-stream, from the

And Admiral Drury says, The advantages of the favourable current do not compensate the *wear* and *tear* occasioned by rough weather; and that the gales, so prevalent in that quarter, extend to 150 leagues from the shore, all along the American coast[1]. He adds, that he is convinced, by the numerous losses sustained in the King's ships, as well as in merchant-vessels, that the route homeward from the West-Indies, merely to benefit by the Gulf-stream, is ill-judged, and has been unsuccessful for a century past.

It has been stated above, on the authority of Sir Philip Broke, that even when the atmosphere was nearly, or at, the *freezing* temperature, it was 80° in the Gulf-stream. It is, without doubt, well understood, that all very wide streams of current, whether warmer or cooler than the ocean temperature, affect the incumbent atmosphere, and reduce it to nearly its own degree of temperature. This

Bahamas towards *Bermudas*, and thence toward the Azores, is generally a *strong set* to the S.W. or W.S.W. During the winter of 1811, and early in the spring of 1812, numerous ships, running passages from the West-Indies, or from Carolina and Florida, to England, were driven 10 or 12 degrees to the westward of their reckoning by this current. We ascertained the fact by speaking many of them: some running on to the Bermudas, and believing themselves in long. 56° west. Other vessels, not 500 miles advanced in their way from Amelia Island, were half that distance wrong in their accounted longitude."

[1] One hundred and fifty leagues from the American coast includes the course of the Gulf-stream through 2400 miles of its extent; and, in effect, all the warm part of it; as, at the termination of that distance, it has fallen ten degrees.

effect is observed more particularly in the Lagullas Current also, in raising the temperature, and in the Equatorial and North-Atlantic Currents in lowering it. It has been noticed that the temperatures of the Mediterranean and Caribbean Seas, and particularly the former, are so much higher than those of the surrounding seas (8° at least), that it appeared to the Author to be one of the probable causes of hurricanes, especially as they happen when the Mexican Sea is in the highest state of temperature, and the excessive cold north and N.W. winds from the continent of North-America, begin to pour in.

It is probable, too, that the temperature of the northern shores of the Mediterranean, adjacent to the warmer part of its waters, (for the narrow parts of it vary little from the adjacent Atlantic,) may very considerably soften the temperature of their atmospheres. For the water of the Mediterranean, in common with all *close seas*, (those not readily communicating with the ocean-waters,) is much warmer than that of the same parallel.

The Gulf-weed or *Fucus Natans*, is a curious accompaniment of the Gulf-stream. Its place of origin does not appear to be settled, but a great proportion of it, at least, is brought out of the Mexican Sea by the stream. Captain Livingston, in his way from New Orleans to the Strait of Florida, saw the sea full of it; and every one that has navigated the Gulf-stream has remarked the weed in it, or along its borders.

But there are different statements respecting this particular:—accordingly, some have said that little

or no weed is seen in the stream; but only on the edges of it, or in the bordering sea; but Sir Philip Broke and Baron Humboldt say that the stream contains a great deal. Sir Philip says, "We were always surrounded with Gulf-weed." He spoke of that part of the Gulf-stream out in the Atlantic: the others might speak of other parts.

The Gulf-weed is found, in vast quantities, in two parts of the Atlantic, appearing to form distinct masses; and is stated, on authority, to be produced on large beds in the bottom of the sea. Of these, one is supposed to lie nearly on the meridian of Corvo and Flores, between latitudes 25° and 36°, long. 30° to 32°, and the other between the parallels of 22° and 26°, about the meridians of 70° to 72°. The first and best known of these floating masses, is described as forming a narrow stripe on the north, but expanding southward to a very obtuse angle. The second is to the eastward of the Bahamas, and its produce is dispersed by the currents on the neighbouring shores[1].

[1] The testimony of the Baron Alex. de Humboldt and others, seems to *prove* that the *fucus* is produced on vast beds in the bottom of the ocean: from these beds it is detached in a *ripened* state, and forms those extensive masses on the surface, which have given name to that portion of the Atlantic called the *Sargasso*, or *Weedy* Sea. It appears, also, to be produced, in great quantities, in the *Mexican Sea:* for, on the 17th of April, 1828, Lieutenant John Evans (*a*), in his passage homeward, (*where no current was perceptible*,) passed through great masses of it; and this gentleman states that, "At noon the vessel was in latitude 26° 52′, long. 89° 17′. On this day *fucus natans*, or gulf-weed, was seen, in parallel lines, S.S.E. and N.N.W. It was in *flower*,

---

PARTICULAR DESCRIPTION OF THE GULF-STREAM, FROM THE COMMENCEMENT OF THE STRAIT OF FLORIDA TO CAPE HATTERAS.

(Written in and subsequent to 1821.*)*

It is certain that the Current of Florida, or the GULF-STREAM, has some very curious circumstances

and completely covered with young barnacles. From the latitude 25° to 28° in this sea, we met with the fucus in parallel lines S.S.E. and N.N.W.: it flowers like fern, and other *cryptogamia.* In calms the fuci float near the surface, some of the leaves appearing above water; the patches which we saw in the Florida Stream, and the bunches examined, were old, brown, and covered with young barnacles.

"The phosphorescent lights observed in the Mexican Sea shine with greater brilliancy than I had noticed them elsewhere: some of these were very large, and flashed like the priming of a gun, sometimes at a long distance from the ship. I observed that the little shining spiracles were confined to the sides of the vessel and her wake, and that the waves, when they broke into foam, did not (as in other parts of the ocean) sparkle.

"The colour of the water in the Sea of Mexico is of a dark indigo, darker or more intense than that of the ocean generally. Phosphorescent lights are equally abundant in the Florida Stream, some unusually large and brilliant; and some of the small lights appeared to spring out of the water, with a sweeping motion, which I had never before observed.

"In November, 1810, H. M. S. Belvedere, in the centre of the Atlantic, latitude 33° 20′, long. 41° 37′, passed through prodigious quantities of *fucus natans,* in line north and south, as far as the eye could see; and notwithstanding that there prevailed a very heavy swell, from the north, their position was not altered. The quantity of this weed met with between the 30th and 36th degrees of latitude is really astonishing; at times you may sail for leagues through it, covering, as a mantle, the surface of the

belonging to it; and that it produces more extraordinary effects, altogether, than any other known Stream of Current. Although, possibly, it does not extend its course to a more distant point than certain other streams, yet it has this particular quality, which is not common to others, that its length of course depends more on its own proper and original movement than any of the others; which are either quickened during their course or renovated by the accession of fresh supplies.

Issuing with great velocity, and in a prodigious volume, from a sea of unusually high temperature[1], it deposits a vast body of warm water in the central parts of the North-Atlantic Ocean; by which, at times, a surface, equal in extent to the Mediterranean Sea, is rendered several degrees warmer than the surrounding ocean: and thus a warmer region of the atmosphere is also formed, in the midst of a colder one, across two-thirds of the Atlantic, between the parallels of 30° and 42°. And it is very justly supposed that, from this circumstance, many

sea: I have often seen it in lines about 300 or 400 fathoms in width, (sometimes only a few yards) and frequently in large and small patches of irregular shape, but generally of a circular form. The deep-sea line should be put over the side frequently in this particular part of the Atlantic."—(*Communicated by Lieut. J. Evans.*)—Ed.

[1] Recent observations show, that the temperature of the Gulf of Mexico is much higher than was supposed. In August (*the maximum*) the waters of the Gulf-stream issue at a temperature of eighty-six degrees. Seventy-seven to seventy-eight is the *ocean* temperature of the parallel of 25 degrees in the Caribbean Sea.

storms arise; as it appears, on examination, that most of the severe gales of wind that have happened in the North-Atlantic, during the last 30 or 40 years, have been either just within, or near, the borders of this expanse of warm water.

A great number of observations of the direction, velocity, and temperature, of the Gulf-stream, made at different seasons, and resting on the best authorities, have been collected and arranged, on the Chart, and in this Memoir. These extend to the *Azores*, generally, so as to give a good general idea of its course; and although authorities are wanting for the most part of its extent, breadthwise, after it leaves the coast of the *United States*, yet a continuous stream of current has been traced.

The commencement of the GULF-STREAM may properly be placed at the outlet from the Sea or Gulf of Mexico, situated between the Bank of *Isabella* on the side of Cuba, and the *Tortugas*, on that of the Florida Reefs; and at about 20 leagues to the westward of the Havannah. Here the clear space is about 20 leagues in breadth; the Streams of Current from the Mexican quarter on the N.W., and from the Caribbean Sea from the S. and S.W., here unite to form the Florida Stream, and proceed to the eastward; but the former is by far the most powerful; so that the strongest part of the stream runs on the northern or Florida side, whilst that towards Cuba is very weak, and sometimes scarcely perceptible.

From the place of entrance, the stream runs first a little to the *northward* of *east*, and then winds round to the *north-east* and *north*; till, in the

course of about 140 leagues from the commencement, it finally opens into the Atlantic Ocean, between the Reefs of Cape Canaveral, on the side of Florida, and the northern termination of the lesser Bahama Bank, on the other, in about the parallel of 28°.

But the *proper Strait of Florida* commences at only about fifty leagues to the N.E. of the outlet from the Mexican Sea, and at 37 to the N.E. of the Havanna, where it is about 15 leagues in breadth, and has become very rapid. At 30 leagues farther on, to the N.N.E., are the *Narrows*, between *Cape Florida* and the *Bemini Islands*, where the space between the lands is reduced to 44 miles; but the *Fowey Rocks*, bank, and the reef extending from *Bemini*, reduce the *waterway* to about $35\frac{1}{2}'$. This is the narrowest part of the Strait, and occasions a farther increase of velocity in the stream, and which continues, for the most part, through the rest of the Strait. Where it opens into the Atlantic, it may be taken at about 50 miles in breadth[1].

[1] These distances were all measured on the large chart of the *Windward* and *Leeward* Passages, constructed by Mr. Purdy.

	Nautic Miles.
Breadth between the Salt Kays, or *Double-headed Shot*, and the Florida Reef, north-westward - - -	48
Between Cape Florida and the Bemini Islands - -	44
Between the Fowey Rocks and Bemini Reef, the narrowest *waterway* in the Strait - - - - -	36
Between the Grand Bahama and the Point near Cooper's Hill - - - - - - - - - -	54

The *waterway* is three less, or *about* 51 miles. This may be reckoned the opening of the Strait to the Atlantic Ocean.

Throughout the greatest part of the above space, the Stream is bounded, and that more commonly on both sides, by a series of reefs and low islands, not visible at a distance. Moreover, a most rapid stream of current sweeps through it; and, in the most critical points of the navigation, the regularity of the main stream is broken in upon, by lateral and oblique ones, either of tide or current, from different channels, which communicate with it on the side of the *Bahamas;* or by the occasional counter current and outlets, at the Florida Reefs. It may be regarded, on the whole, as one of the most critical navigations known; when the length of the way (400 miles), and the dangers of so many different kinds that beset it, are considered.

From the *outfall* of the Stream, between Cape Canavarel and the Bahama Reef, it continues nearly on a north course, or with a very small inclination to the eastward, (taking its direction from off the Strait it has passed,) pointing *towards* Charlestown; and its inner border is described to approach within fourteen leagues of *Savannah,* where it is turned aside by the edge of the Bank of Soundings. Thence it runs nearly parallel with the coasts of the Carolinas, on a straight course of E. 40° N., or about N. E. ½ E. to the neighbourhood of Cape *Hatteras,* a distance of about 100 leagues.

Report allows 20 to 21 leagues for the breadth of the stream opposite *Charlestown,* 24 or 25 opposite *Hatteras;* and this agrees nearly with Sir Charles Blagden's idea, of its being twenty leagues

broad off Cape Fear, which lies between Hatteras and Charlestown, but nearest to the latter. It has been said that the inner edge of the Stream is at 19 leagues from the Bar of Charlestown; but from a detailed Chart in the *American Pilot*, and the general result of the authorities, it ought to be no more than thirteen.

According to the same *American Pilot*, the inner edge of the Stream passes on an E. 40° N. course, at the distance of 24 miles S.E. from Cape Hatteras, and in 60 fathoms of water. The extremity of the shoal, or reef, off the Cape, lies between, at one-third over from the land, with 12 fathoms close to it[1].

If it be true that the Stream is 25 leagues broad at Hatteras, it will have diverged about one-half of its original width, at its leaving the Florida Strait, in the course of about 166 leagues.

We shall next proceed to trace the Current itself, through the Strait, in a general way, in respect of its lines of direction and velocity.

The discharge or overflow of the Sea of Mexico, has already been described, in page 187, as forming a stream of about sixty miles in breadth, on its entering the Strait of Florida, at about a like dis-

[1] The same Chart places the inner edge of the Stream at E. 44½° S. 49 miles from Cape Fear, and in 95 fathoms. It gives no information concerning the breadth of the Stream.

Some notices from H. M. S. *Beaver*, state, that at 30 miles S.E. from the Charlestown Light-house, they had 22 fathoms, and were told that the soundings extended 70 miles off shore, into lat. 32° 30′.

tance, short of the Havanna. But the strength of the Stream is confined to the centre and the Florida side; probably because the main part of the discharge comes down along the western side of the great Florida Bank. On the side towards Cuba, the Stream is very weak, as far as the Salt Kays, where the Strait of Florida commences.

The long-extended chain of Florida Reefs and Kays, which bound the northern side of the Stream, between the entrance and the Strait of Florida, has some degree of *curve* or *bend*, to the south, so that the bearing becomes gradually more and more northerly, as we advance eastward. Such being the case, and currents not suddenly changing their direction with that of the shore, or of the reefs, it happens that the line of current here, bears somewhat off, from the coast of Florida, towards the Salt Kay Bank[1], and the Great Bank of Bahama; and this takes place, in a still greater degree, between the entrance of the Bahama or Old Channel and the Orange and Cat Kays, towards which it decidedly sets; owing chiefly to the *quicker turn* which the Strait now takes, to the *left* or northward, but partly also to the widening of the space, opposite to the entrances of the Old Bahama and Santaren Channels.—[See Chart V.] And this bearing off of the Stream, from the Florida coast, is not confined to its northern border alone, but extends to the great body of it, which falls partly on the Great Bank of Bahama, partly on the Salt Kays:

[1] Called also the *Double-headed Shot Bank*, and the *Bank of Anguilla*.

but, receiving a check from the former, the Stream turns to the northward, and soon after enters the NARROWS, where the strait channel commences, and thence all is strait to the opening into the Atlantic, and to the parallel of 31° north.

That part of the Strait between the Salt Kays and the Narrows, may be regarded, on all accounts, as very critical. The opening of the Bahama and Santaren Channels, which have *tides*, and which casually affect the current in the Strait; the just-mentioned *obliquity* of the thread of current itself, together with the indraught through the opening, called the *Great Inlet*, into the *Hawke Channel*, all conspire to mislead. There is yet another source of evil, equal to, or even greater than any one of the others; which is a *counter current* to the S.W., along the side of the Florida Reefs; and which is the more dangerous, as not being sufficiently known. It is no doubt the cause of so many ships having been thrown ashore on the narrow insulated chain of reefs, which extend along, parallel to the Islands, forming the northern side of the Strait, from the front of the Havanna to the Narrows of the Florida Strait. The comparatively narrow channel between this chain of reefs and the Islands, is the *Hawke Channel* above-mentioned, through which lies a very safe passage to the south-west and westward, for small vessels[1].

[2] The names of the reefs and rocks, chiefly taken from the ships which have suffered, present an awful warning, and seem to demand *day-light* or bright moon-light for the navigation.

This counter current is said to run at all times, save when northerly and westerly winds prevail. It appears to commence near the *Narrows*, and to extend nearly to the *dry Tortugas*, westward. No precise idea is given of its *breadth* or *velocity*, but it seems to be considered as having a breadth of about a league or more; and to extend 2½ leagues or more from the chain of Florida Kays, the *Martyrs*, &c., and to be in strength. It seems to owe its existence to the bearing off of the Great Stream from the Florida coast, towards the Great Bahama Bank, which leaves, of course, a space unoccupied between it and the shore; whilst the *Narrows*, having too little space to admit the whole body of the stream, when it turns to the north, to enter them, a part of it returns through the unoccupied space. Instances of a like kind occur in other straits and in rivers.

One cannot but suppose that, at times, this stream of *counter current* is much broader than is above stated. Such a multitude of ships, and amongst them several of his Majesty's, have been carried either on the Reef or through the Great Inlet, into the *Hawke* Channel, in latter times. These could not generally have held their courses within a league of the Reefs. It is, therefore, most probable that the indraught of tide into the Santaren Channel may, at times, draw the Great Stream more to the east, and thereby increase the space between it and the Florida shore; and thus give a wider scope to the counter current.

The Great Inlet also, itself, through which a por-

tion of this counter current *sets* into the *Hawke Channel*, appears to have produced a great many shipwrecks and narrow escapes. It has been remarked that most of the accidents happen very near this place, by its *indraught*; aggravating the evil of the counter current. Many persons are not aware of the extent to which the surface of an expanse of water is affected by an outlet from it. For, as the water approaches the opening from all quarters, in *converging* lines, a large *semicircle* of *indraught* water is in motion. From whatsoever causes these mischiefs may arise, they are unequivocally known to exist; and therefore it behoves all persons to avoid this side, and particularly this quarter of it, during the night, when the state of the currents cannot be so well ascertained.

The Great Inlet is 16 leagues above the *Narrows*, and directly opposite to the *Orange Kays* on the Bahama Bank. The *Larne*, which was drawn into the Great Inlet, in the night, in 1816, and into $2\frac{1}{2}$ fathoms, made its latitude 24° 54′. They described the current which carried them out of their course as a W.S.W. current [1].

To return to the subject of the *velocity of the Great Stream*.—It appears, from the numerous ex-

[1] It has been said, that the northerly winds put an end to the S.W. or counter current; but it cannot be supposed that they have a like effect on the *indraught* of the *Great Inlet*. The *contrary* would rather be supposed; for a strong northerly wind must necessarily impede the stream, and keep its surface up to a higher level: whence must be expected *a greater flow of water through the channels that lead to the N.W.* through the *Martyrs* and *Florida Kays*...

amples before the Author, that it varies, not only with the seasons, but that there are exceptions (as might be expected) to this rule[1]. Also that it is greatest when the sun is far to the north; or on its *return* to the neighbourhood of the Equator: being influenced by the prevailing winds, as we have already spoken of most fully.

The detailed Chart of the strait and its neighbourhood [CHART V.] will best show the positions in which the several observations were made. Hereto is moreover annexed a TABLE of VELOCITIES, distinguishing the different rates in different parts of the Strait; by which it will appear that the *compression* of the stream at the Narrows increases the velocity very considerably; and that it does not diminish, in any considerable degree, in the course of sixty leagues beyond the opening of the strait into the Atlantic. Generally speaking, the current of the Mexican Sea, previous to its entering the strait, is about a mile and a half *per* hour; after entering it, this current increases to 2½, 3, and occasionally 4, miles. On being compressed, laterally, at the Narrows, it is often 5, at the *maximum*, in August; and seldom below four

[1] As an example, take the following reports for March, in different years:—

March, 1795, by Don Francisco Alcedo, below the Narrows, ...	97 miles in 24 hours.
Above the Narrows	97
March, 1815, H. M. S. Gorgon, at the Narrows	120
Above do.	80
March, 1819, Capt. Livingston, below the Narrows	50
Above do.	34, 34, 31

throughout the rest of the Strait, which extends 50 leagues beyond the Narrows. And finally, beyond the mouth of the Strait, to 31° N., it is $3\frac{1}{2}$ miles. This must, however, be understood to mean the *central* and strongest part of the stream; since, towards its borders, it is much weaker, and the temperature lower. This latter circumstance indicates, to observant persons, a general idea of their position in the stream during the night.

In latitude 32° the rate was nearly $2\frac{3}{4}$ miles in *April* and *September*. But the authorities fail generally, between that and Cape *Hatteras*, in about latitude 35°; because ships bound to Europe, more commonly leave the stream, as soon as they get a favourable wind for cutting off the angle which would arise in their course; and do not enter the stream again, till far to the eastward of Cape Hatteras. But it is pretty well understood, that the rate, within this interval, is from 3, decreasing to $2\frac{1}{2}$ miles: and Captain Livingston had 68 miles per day, or $2\frac{3}{4}$ miles per hour, off Cape Hatteras, in August, with a temperature of 83° in the beginning of September, which may be reckoned the *maximum*.

It will be proper in this place to mention, that there is a regular *counter current* setting in an opposite direction to the Gulf-stream along its *eastern* border, the whole way from opposite Cape Hatteras to the opening of the Strait. But as this is only a part of a counter current, which appears to extend from about the *Azores*, it will be better that the whole subject should be considered to-

gether; after that of the direct stream has been completed.

The Author cannot quit this neighbourhood without adverting to the peculiar form and disposition of the islands, kays, and banks, which compose the Archipelago of the *Bahamas*. The general shape of these islands, &c., together with their relative position to each other, and the numerous strings of low kays and shoals by which they are connected, have, on the whole, a strong resemblance, in point of disposition, to the alluvial islands and sand banks formed by the currents of rivers. Indeed, they cannot, without difficulty, be referred to any other cause than the passage of powerful streams: and this seems to show that the *outfall* of the Gulf of Mexico lay, at some remote period, through the *eastern* channels of the Bahamas; and that it varied its course, in like manner as rivers do, by creating mounds in one part, and excavating new channels in another.

If such a state of things ever existed, the meteorology of the northern part of the Atlantic must have been very different when it had not that vast surface of warm water which it now has; and which, by intercepting and so quickly annihilating the ice from the Arctic regions, ameliorates the atmosphere of those parallels.

In the former case, the stream, instead of passing towards the *Azores*, and into a sea many degrees colder than itself, would probably have pointed towards the Cape Verde Islands, through a sea much nearer its own temperature.

VELOCITIES OF THE GULF-STREAM, IN THE DIFFERENT PARTS OF THE STRAIT OF FLORIDA, AND AT DIFFERENT SEASONS.

	From the entrance to the Narrows at Bemini.				Narrows to the opening into the Ocean.				Beyond the opening to Latitude 31°.				Mean of all.		Mean from Narrows to 31°.	
MONTHS.	No. of Ex.	Mean rate in 24 h.	Maximum	Minimum	No. of Ex.	Mean rate in 24 h.	Maximum	Minimum	No. of Ex.	Mean rate in 24 h.	Maximum	Minimum	No. of Ex.	Mean rate in 24 h.	No. of Ex.	Mean rate in 24 h.
		Miles.	Miles.	Miles.		Miles.	Miles.	Miles.		Miles.	Miles.	Miles.		Miles.		Miles.
January																
February																
March ...	7	54½	97	34	5	72½	120[1]	31	1	97	97	9	13	72	6	71
April	—	—	—	—	—	—	—	—	2	33½	34	3	—	—	2	33½
May.....	7	51½	72	36	1	80	Humboldt		—	—	—	—	7	51½	—	—
June	1	72	72	72	1	60	60	60	—	—	—	—	2	66	1	60
July (end)	4	24	48	12	1	69	96	96	1	80	80	80	6	46	2	88
August ..	5	63	72	35	3	103	120	78	1	84	84	84	9	78½	4	98
September	2	42½	57	28	—	—	—	—	3	84½	88	78	5	63½	3	84
October ..	2	46	62	32	2	25	26	24	3	39½	65	15	7	37	5	42
November	2	18	22	14	1	70	70	70	—	—	—	—	3	44	1	38
December	4	26½	48	12	2	77	79	75	1	38	38	38	6	31	3	64

PARTICULAR DESCRIPTION OF THE GULF-STREAM, FROM CAPE HATTERAS, EASTWARD. [CHARTS II. and V.]

(*Written in* 1822.)

After the GULF-STREAM has changed its course to *seaward*, in the manner described in page 162, it proceeds through the Atlantic, at large, on an east-northerly course, to the distance of more than

[1] By H. M. S. Gorgon, Captain W. King, whilst running down the N.E. trade from Bermuda.

500 leagues; or to the longitude of 43° or 44°, between the parallels of 41° and 44°; where it is still found running on the same *general* course as at the place where it leaves the coast; and as more than 200 leagues of its *intermediate* course are known to run in the same direction, little doubt can arise concerning the remainder of it.

Having reached this point, it gradually changes its direction from *east, northerly*, to *east*, and S.E, and finally southward; inclosing within its eastern border the Islands of *Corvo* and *Flores*, near the parallel of 40° N. and about 31° W. This latter part of its course occupies about 190 leagues, and completes a course of about 3060 miles from the place of its issuing from the Sea of Mexico. And thus far, and no farther, the existence of a *current* of *warm* water can be *traced* by ships' reckonings; but as gulf water, of four degrees above ocean temperature was found by Captain Livingston, 1st Oct. 1818, to extend to Fayal, 40 leagues E.S.E. from Corvo; and Dr. Franklin, in the summer of 1785, found the sea five degrees above ocean temperature, of the season, as far south as lat. 34°, or farther, in about 5 or 6 degrees to the westward of the meridian of Corvo; it may be concluded, that, either the stream extends thus far at times, but is too weak to be detected by ships' reckonings, or that it was only the *spreading* of the warm water, deposited by the stream, in a part which may be considered in the nature of a *recipient;* for, as the stream is incessantly bringing on fresh supplies of

warm water, these must necessarily be deposited somewhere or other.

It may also be remarked, that the vast mass of gulf weed brought by the stream, and so well known by its lying in the usual track of ships that sail up the N.E. trade, extends southward in the general line of direction in which the stream *appears* to terminate, to lat. 20°, and sometimes to 19°, or more than 1200 miles from N. to S. The permanent position of this mass seems to indicate occasional extensions of the gulf water, in this direction also, as well as to mark the region itself, as the grand *recipient* of the gulf *weed*, as well as of the gulf *water*.

It is only occasionally, however, that gulf water is found so far to the south as Dr. Franklin describes it; for, in the summer of 1791, Captain Billings passed two degrees to the northward of Dr. F.'s track, through water of ocean temperature; and again, in April, 1819, Captain Alsager crossed the track of Dr. F. northward, and found ocean temperature also, not only *there*, but even to a considerable distance to the *westward* of Corvo. And, finally, Captain J. P. Wilson, in the same year, found ocean temperature across this part of Dr. Franklin's track.

There is little question but that, at times, the ice which, during the spring and early part of the summer, is carried in vast quantities into the Gulf-stream, from the northward (and has been seen in lat. $40\frac{3}{4}°$, late in June) very materially affects the

temperature of this *zone* of its waters: and, finally, the extension of its waters to the coast of Europe, as happened in one year (1776), shows how very uncertain the course of this wonderful stream is when it approaches the Azores; which, so far as experiments go, appears to be its *ordinary* place of termination.

Materials are wanting for the *filling up* of one large proportion of this great extent of course; nor is it surprising, considering the vastness of the whole. A *general* description only could be aimed at, at any rate; but even the information necessary for this purpose is wanting, throughout more than one-half of its course, after its leaving the coast. I shall proceed to give a general idea of the state of the information. It may be said that nearly one-third of its hydrography is unknown *in detail*.

It has been shown, that, from a point about 20 leagues to the eastward of the entrance of the Chesapeake, and between 37 and 38 degrees of latitude, Captain Pell, in 1815, found an E. by N. current, at the *mean* rate of 47 miles per day, through the space of 85 leagues, to longitude 69°. This was between the 26th and 29th of *August*; and, on the 6th of the same month, Captain Rodd, at the distance of only 15 leagues E.S.E. from Captain Pell's advanced station, had found a current of E. 14° N., 51 to 66 miles per day, and which he experienced three days, through a course of 110 leagues, to about long. 61°. The mean direction of the current, during the three days, was E. by N., and mean rate 56 miles. Taking the account from

the most westerly station of Captain Pell, to the most easterly station of Captain Rodd, the general direction of the current was E. $12\frac{1}{3}°$ N. and distance 210 leagues; between the parallels of 37° 22′ and 39° 30′, and long. $74\frac{1}{2}°$ to $61\frac{1}{4}°$. This result seems to be fairly indicative of the direction and force of the Gulf-stream at that season (August), and in that quarter, through thirteen degrees out of the 33° of longitude, on which it commonly runs, on a course of about E. $\frac{1}{4}$ N. through the Atlantic.

Again, Captain Pell, between the latitudes of 39° and 40°, and longitudes 62° and 64°, (which was to the N. of Captain Rodd's track,) had found a current of 48 miles per day, E. 16° N.; that is, two degrees more northerly than Captain Rodd's observations, and 4° more than the compound line of 210 leagues. Captain Pell's observation was made only 18 days previous to Captain Rodd's, in the same quarter; and five weeks previous to *his own*, near the Chesapeake. So that all the three sets of observations were made within the course of six weeks; which is fortunate, as proving a general direction and rate of current over a large extent of the course of the stream.

But here the knowledge of the detail terminates *on this side;* for Captain Rodd, who had noted the direction and rate of the stream to the before-mentioned station (in lat. $39\frac{1}{2}°$, long. $61\frac{1}{4}°$), and had flattered himself with the expectation of noting the remainder of it, at least, as far as lay in his way, was driven out of it to the northward, by a hurricane, in lat. 40° 29′, and long. 59° 58′, on the 9th

of August; and, although some observations were made by the way, it may be doubtful whether the surface current had not been affected by the storm.

In long. 50°, lat. 39°, and in long. 45°, lat. 40°, the course of the stream was again marked, on board of H. M. S. Queen, in 1800; by Captain Beaufort, in 1809; and by Captain Rodd, in 1815; respectively; and continued by the Queen to long. 41°, in lat. 41°; soon after which the stream turns to the S.E., so that a portion of the stream, which is absolutely unknown to experiment, lies between the meridians of 50° and 61°, equal to 170 leagues in extent: and another interval of about 5° of longitude, between the place where Captain Beaufort left the S.E. current, in longitude 40°, and his entering the east-northerly current in longitude 45°. He was then going westward. Within this interval, it is concluded that the Gulf-stream turns to the east and S. of E.; as the facts concerning the existence of the S.E. and southerly currents, towards *Corvo*, are clearly ascertained.

The Breadth of the Stream, in its way through the Atlantic, is with difficulty obtained; by reason of the expansion of the warm water, on both sides, beyond the stream, and other causes; even though it has been repeatedly crossed in the same place, and registers of the extent of the warm water carefully kept. But no tracks across it, farther to the eastward than long. 63°, have come to the Author's hands. It is between that meridian and 68°, that ships, and particularly those of his Majesty, cross it, in their voyages from Bermudas and the West-

Indies, to Halifax, Boston, &c. With these he has been most liberally supplied, by Mr. Napier, of H. M. S. Newcastle.

It may be conceived that the cause of our ignorance of certain particulars respecting the Gulf-stream in the Atlantic, at large, is, that a knowledge of them, though highly useful, is less so to navigators in that part, than in its course along the Southern States of America. Within that space it is constantly crossed in the tracks to and from its southern ports. There, the American navigators attend particularly to its extent and temperature; since a knowledge of those particulars serves to correct their reckonings, when approaching a dangerous coast; but they have no inducement of this kind when crossing the stream in the ocean at large. Moreover, it appears probable, that, by reason of the sudden expansions and contractions of the warm water, little information would be conveyed, by solitary experiments. But whilst confined to the coast, the stream has less tendency to spread, and affords a sure guide to navigators.

The stream, in its course through the Atlantic, is generally crossed under circumstances which prevent a knowledge of the exact time when the observers pass into or *out* of it; the observations being necessarily made only *en passant*, and in the course of other duties; so that few opportunities occur of adjusting the boundaries of the stream to the celestial observations. To this it is owing, that, although in a great number of instances, the extent and temperature of the warm water have been

obtained; yet, partly from the ambiguity arising from the diffusion of the warm water beyond the borders of the stream, and partly from the bad weather so frequently occurring within it, the breadth of the stream could not be ascertained. However, *approximations* have been made, so as to convey much *useful* information respecting the positive rate and direction of the stream: and still more *curious* information is collected, respecting the temperature and extent of the Gulf-waters, and their astonishing variations in the same places, at different times, in the *western* part of the stream; the only quarter in which these experiments have been made in such a mode as to afford the means of accurate comparison.

Thus, then, notwithstanding the great mass of information which we *do* possess, relating to the general subject of this stream, the means of its delineation, *as a whole*, are still deficient. This, however, ought not to excite surprise, when it is considered that it extends *several thousand miles*, and is generally navigated only by piecemeal; since it does not often happen, that ships hold their courses through any great proportion of it during one and the same voyage. Add to this, the lateness of the discovery of the means of obtaining the longitude at sea; previous to which the details of currents were absolutely unattainable: as also, our long ignorance of the difference of temperature of the stream, and of the ocean which it passes through.

Nor has its hydrography, or that of its *counter currents*, even since those discoveries, engaged the

attention of any one of the maritime powers, so as to induce a systematic examination and inquiry into those particulars; although such a knowledge would doubtless be productive of advantage to navigation, particularly in voyages to and from the north-eastern part of America: that is, to point out the means of profiting by the stream, altogether, when necessary, and how to profit by its counter currents. As to its *real utility*, in affording a help, equal to a few days' sailing, in the returning voyages to Europe, it is perhaps, on the whole, overbalanced by the probabilities of bad weather which so frequently occurs, *within*, or *near*, *its borders*.

From what has already appeared, it is unquestionable that the Gulf-stream does not uniformly keep to the same line of course; and it will be found, from the same and other authorities, that similar circumstances take place in its course through the ocean. For, by the numerous experiments that have been made in latter times, and chiefly within these very few years past, on the setting of the currents in various places, and on the temperature of the sea; the above fact is completely proved. In respect of the boundaries of the *stream*, however, accuracy cannot be expected, from the reasons before stated.

The great extent of latitude, through which the Gulf-water has been traced, at different times, under nearly the same meridians, had led many persons into error respecting the breadth of the stream; until a course of experiments proved that

the Gulf-water varied its place very greatly. It must now be well understood, by the reader, that the presence of warm water is not, by any means, a proof of the presence of the Gulf-stream; because, not only does that stream frequently *overflow*, in the nature of a *swoln* river, but a counter current of the returning *warm* waters to the westward, commonly prevails to the southward of the stream.

This overflowing, or expansion, of its waters, renders it, of course, extremely difficult to ascertain the breadth of the *stream itself*, even by the aid of a knowledge of the extent of the warm water: that is, where the main stream ends, and the counter current, or still water, commences.

It has been ascertained, particularly by Mr. Napier and Mr. B——, in the line between Bermudas and Halifax, where four crossings were made in the same place, that the breadth of the warm water varies, at times, in the proportion of more than *two* to *one*, (*i. e.* from 140 to 320 miles,) and within the space of ten weeks. But the most *sudden* changes are also observable. In the month of May, 1821, between the 10th and the 17th, the breadth varied from 248 to 186, and from the 17th to the 28th, again from 186 to 240 miles[1]: and

[1] As the variations in the strength of the stream, at the Strait of Florida, are from 2½ to 5 miles per hour, at different times, this may account for the sudden changes in the breadth of the Gulf-water in the Atlantic. For instance, a velocity of 2½, or 60 miles per day, in the narrowest part of the Strait, being 36 miles broad, will pour into the Atlantic each 24 hours, more than 2000 square geographic miles of water, and the depth may be sup-

yet all these three traverses were made within the space of about a degree of longitude; and sometimes even crossed each other. The increase seems to have been chiefly to the southward [1], as if from *offsets* or *overflowings* on that side.

Nor do these changes follow any regular course of seasons; for the Gulf-water was 320 miles in breadth in May, 1820, and only 186 in May, 1821, nearly in the same place.

Besides the information derived from the valuable documents above specified, the fact of there being *warm* and *cold* water at different times in the same place, is satisfactorily proved, by means of a considerable number of reports of the temperatures in other parts of the stream, along, or across, the usual course of it. Water has been found of 8° *above* ocean temperature at one time, and at ano-

posed to be very great; that is, worn down by the rapidity of the stream; and consequently a very great capacity of spreading will be afforded. By the time it reaches Cape Hatteras, 640 miles from the Strait, it has already spread to 72 or 75 miles, or more than doubled its original breadth; and in long. 63°, 600 miles farther on, Captain Pell reports its breadth 140 miles, or four times its original breadth. With this capacity of expanding, we may suppose that a sudden and great increase of velocity must very materially affect the breadth of the Gulf-water in the Atlantic.

[1] It seems probable that the stream, which naturally has a tendency to spread, would expand more readily on the side towards the ocean, which presented no obstacle, than towards the land and the banks projecting from it, which *shut it up* on that side. And that this happening in the first instance, the impulse continued throughout. This might also account for the stronger current on the northern part of the body of warm water.

ther, as many degrees *below* it, in the same spot; and that at a full degree and half of latitude to the northward of the extreme limit of the warm water, at a former period.

I come now to particularize the above-mentioned valuable documents.

No less than *ten* different *traverses* or *crossings* of the Gulf-stream have been furnished to the Author, between the longitudes of 63° and 72° west; in which the temperatures of the Gulf-water have been registered, and in all, save one, in *detail.* These afford the means of comparing the temperatures at different seasons, as well as the variations, in respect of situation and extent, of the warm water. Of these *ten*, one has been already considered, in the description of the turning of the stream from the coast of America, (to which it more particularly applied,) in the last section. Besides these, there are no less than seventeen others, by Captain Tozer, R.N., in the years 1819, 1820, and 1821, which apply to the currents alone, and which are highly satisfactory, as being made in ten different months of the year, and by the same person. Captain Tozer reports, in his chart sent to the Admiralty office, that the stream "varies its situation from lat. 37° to 42° N., between the longitudes of 62° and 66° W.;" but that "its breadth seldom extends to more than 100 to 120 miles, in whatsoever latitude it is met with." By his chart it appears that he *rarely* found any easterly current to the southward of 37°; and only in two instances to the northward of 41°. And it

will be found by the result of the authorities, taken together, that the Gulf-stream is most commonly found between the parallels of 37° and 40°; and that the few examples of easterly currents that occur beyond those limits, are to be taken rather as *extreme cases* than otherwise.

Of the first-mentioned tracks across the stream, which mark the temperature of the water, five are by Mr. Napier, three others by Mr. B—, one by Captain Pell, of H. M. S. Menai, and the tenth from the Maidstone Frigate. The investigation of these documents, however tedious it may be deemed, is absolutely necessary towards a right understanding of the subject.

Nothing less than a display of these *traverses*, in the form of a chart or diagram, with references to the details in the text, can enable the reader to form a just idea of the changes that take place[1]. I shall begin with the five which lie immediately in the line between Bermudas and Halifax; because, from their number and juxta-position, they are the best adapted to convey the clearest idea of the subject; whilst those which are situated higher up, in respect of the stream, will be better understood by being treated of after these.

It must be regarded as a fortunate circumstance, that so many examples of the temperature should have been furnished within nearly the same space, by able and attentive persons (all *volunteers*); as

[1] The Appendix includes a Table, in which the comparative latitudes, temperatures, and distances, are arranged.

with these, and the observations on the currents by Captain Tozer and others, within the very same space, a very fair specimen of the nature of the Gulf-stream, in that state of its progress, after having advanced 500 miles into the Atlantic Ocean, is exhibited. And, it may be added, that the result of the application of so many observations to one and the same part of the stream, may furnish the reader with some general ideas respecting *others* of those vast streams, which, like rivers, take their courses through the ocean; since it may be concluded that they are all subject to the same general laws, but which escape our notice: first, because observations are seldom *repeated* in the same place; and, secondly, because the difference in their temperatures from that of the ocean is not sufficiently marked to detect the changes, as in the *Gulf-stream.*

From the circumstance of the *five* traverses, which are about to be considered, being so nearly under one meridian, the comparisons of the extent, and of the relative position, of the warm water, at different times, can be easily made by a reference to the parallels of latitude. But in the cases where the other traverses differ much in respect of meridians, recourse must be had to a different kind of standard. For, as the general course of the Gulf-stream through the Atlantic is *oblique* to the parallels, *they* cannot be referred to with effect; but the reference must be made to an imaginary *central* line passing through it.

The general direction of the Gulf-stream through

the Atlantic, after it has finally quitted the American shore and its contiguous banks, taken on a mean of the different authorities, is about E. by N. $\frac{1}{4}$ N. (or E. 15° N.) Captain Tozer, who furnished the greatest number of examples, under nearly the same meridian, reckons it E. 22° N. about the meridian of $63\frac{1}{2}$°; but Captains Rodd and Pell, as we have shown, on a run of 210 leagues, between the longitudes of 68° and 61°, on a mean, E. $12\frac{1}{3}$° N.; Captain Pell, about the meridian of 64°, E. $19\frac{1}{2}$° N.; and the Queen, E. $8\frac{1}{2}$° N. Mean of the three, E. $13\frac{1}{3}$° N. And between the longitudes of 43° and 49°, the mean of four examples, by three different persons, in as many different years, was E. 18° N. Thus the latter examples, at the distance of 300 leagues to the eastward of those of Captain Pell and Captain Rodd, before-mentioned, differ only about five degrees, and from Captain Tozer eight degrees. The general mean of all was E. 17° N., including the examples *across*, as well as at *length*, through the stream. But I have adopted E. 15° N. in adjusting the *central* line between the Chesapeake and longitude 61°, as agreeing best with the examples *through* the stream in that quarter, and where alone the references are to be made.

A[1].—*The first traverse* (marked A. A. in the chart) was made by Mr. Napier, in February, 1820. In it the northern limit of the warm water,

[1] These capital letters, A, B, &c. correspond with the Charts II. and V.

between longitudes 63° and 64°, was in latitude 39° 45′, and southward it extended to latitude 37° 20′. The length of the whole traverse across was 146 miles, but in a south direction, and consequently oblique to the course of the stream. When reduced to S. 15° E., or directly across, it is 140 nearly. This is the most compressed state in which the warmer water has yet been reported. Captain Pell, in July, 1815, reckoned the *stream itself* of the same breadth between longitudes 63° and 65°, but his register of the temperatures is incomplete. The highest temperature, in this traverse of February, was 67° or 9½° above ocean temperature, and this was in latitude 39°.

B.—*The second traverse* (B. B.), by Mr. Napier, also took place in the month of May of the same year (1820), only ten weeks later than the former; yet the breadth of the warm water was considerably more than *double* that of the other, and is the widest example of all; being 320 miles across, reckoned direct. It extended northward to latitude 40° 33′, (46′ beyond that of February,) and southward to latitude 36° 13′. So that the central part of it extended to a point little short of the *southern extremity* of that of February.

The highest temperature in this traverse was 73°, or 10° to 11° above ocean temperature; and this temperature extended from latitude 36° to 39°.

C.—*The third traverse* (C. C.) was made during the May of the following year (1821), and in point of contractedness was next to that of February,

1820, which was 140, and this one 186, miles. It extended northward sixty miles beyond that of February, and to latitude 40° 35′. Southward it terminated nearly at the same place with the traverse of February, 1820, or in latitude 37° 31′.

A circumstance occurred in the course of this traverse which deserves notice. After Mr. Napier had advanced northward 36 miles through Gulf-water of 70° to 71° of temperature, (*i. e.* 7° or 8° above ocean temperature, he came into water of 66° and 67°, and which continued 32 miles, onward to 38° 48′, where the temperature again increased to 70° and 72°, until he arrived in lat. 40° 12′.

Mr. Napier remarks, that there was "a *cross* and *confused* swell, with every appearance of current, whilst in the *higher* temperature, but that the water was *smooth* during his progress through the *cooler* vein[1]." The *disturbed* state of the sea with the *higher* temperature, and *smooth* state with the lower, seems to show that the strongest current will be found with the warmest water.

D.—*The* FOURTH *Traverse*, (D. D.) in this series, is by Mr. B—, between the 8th and 10th of the same month of May, 1821; that is, only eight or nine days previous to Mr. Napier's (the last). It was generally parallel to his route, and little more than 20 miles to the westward of it, and once even crossed it. Yet the breadth of the warm water was 248 miles, or 62 greater than that found

[1] I have met with the same kind of cold veins in the Lagullas Current.

nine days afterwards! This increase of breadth consisted in its greater extension *northward*, even to 41° 20′, and which is the farthest point of warm water northward, in this meridian, (between 64 and 65°) that I find recorded in these documents, and is no less than 95 miles above the highest northern point in the Traverse (A.) of Feb. 1820! The temperature was here (in 41° 20′) 68° in the beginning of May, or 8° above ocean temperature. On the south, its extent differed little from the traverse of February, just mentioned, being 37° 12′; so that Gulf-water, of 8° above ocean temperature, has been found in the beginning of May, in lat. 41° 20′, and at 7°, at the same season, in the preceding year, in lat. 35° 13′, which, taken *directly across the stream*, is nearly equal to 390 miles, or more than 85 greater than the variations opposite the Chesapeake! So great are the variations in the extent and place of the warm water. The temperature in this and the third traverse, which was nine days later, differed only *one* degree, although taken by different persons and with different thermometers; that of the latest date was the highest.

More will be said respecting the temperature of the *northern part* of this traverse in the sequel, as I mean to compare together the temperatures of the *three contiguous traverses*, in May, 1821; there being something remarkable in the differences between them, in that part.

E.—*The fifth Traverse*, (E. E.) in the same series (the 2d of Mr. B.'s) was made on the 27th and 28th of May, 1821, being the third in the

course of the same month, and about twenty days after his former traverse, ten days only after Mr. Napier's.

The breadth of the warm water in this traverse, was 240 miles; but although agreeing in this respect, so nearly with his former one, yet it was comprised within different parallels; for it fell short of the extent of the former, northward, by 46 miles, but exceeded it, southward, nearly in the same proportion.

However, the parallel to which it extended northward, coincided almost exactly with the two other traverses of the 8th and 18th of the same month, in the different years, 1820 and 1821.

The temperature in the southern half of this traverse, exceeded by 3 or 4 degrees the observation of Mr. B., made twenty days before, in the same line, (for it actually *crossed it twice)*, but agreed in the northern part.

A circumstance occurred here, similar to that which happened in Mr. Napier's traverse of the 17th May; a space of cold water of 54°, or 7° below ocean temperature, was found between other temperatures of 68° and 72°. This was in latitude $39\frac{1}{2}$°; but Mr. Napier's happened at a whole degree of latitude farther to the south; and the temperature, although 4° or 5° *below* the surrounding Gulf-water, was still 3° or 4° *above* that of ocean temperature, but *here* it was *below* it.

It may be observed by the Chart (V.) that, at times, water *unusually cold*, has been found in the quarter adjacent to the place of the 54° above-

mentioned, on the west and north-west. In one instance, in the beginning of March of the year in question (1821), it was only 44°, although short of the parallel of 40°, that is, 16° below ocean temperature; and, at the same time, in lat. 40° 40′, it was so low as 36°, in the same place where Captain Billings had 75° in Sept. 1791.

In effect, the temperatures *beyond the northern extremity* of this traverse of the 28th May, compared with those of the 8th and 18th of the same month, afford much information respecting great and rapid changes that take place in the positions of the warm water, in this part at least.

It may be seen, by a reference to the Chart, that the warm water of the 28th May, 1821, (E.) terminated on the north in lat. 40° 34′, where it was 68°, or 7½ degrees above ocean temperature; exactly the same temperature as Mr. Napier had experienced ten days before, and where also he found the termination of the warm water to the northward. Thence, passing on to the N.N.E., about 5 leagues, the temperature sunk to 54°, or about 7° *below* ocean temperature. But in *the same spot* Mr. B—, found 72°, or 18° higher, only ten days before! This is, no doubt, very remarkable; but it is equally so, that, proceeding 32 miles to the northward, to 41° 20′, Mr. B. still found the temperature 68°, although Mr. Napier, ten days before, at seven or eight leagues farther to the westward, found only 44°!

These changes in temperature, so sudden and so great, as from 54° to 72°, and 44° to 68°, in the

same place, in the course of ten to twenty days, would appear too improbable for belief, was it not known that, besides the neighbourhood of the immense fishing banks, which cool so vast an extent of the sea, adjacent to the coasts of New England, &c. *Ice Islands* are often seen in that sea, in the spring and great part of the summer. These are known to cool the water sensibly, to the distance of 40 to 50 miles around them; and at the distance of 25 miles, to sink the thermometer no less than 17 or 18 degrees; that is, from 61° or 60°, to 43°. In effect, cooling a circle of water of 80 or 90 miles in diameter! Two of these circles were sailed through by the *Eliza* packet, in April and May, 1810, the westernmost in lat. 42°, at a point 60 leagues to the eastward of the cold water just mentioned; the other circle some degrees farther to the eastward. Moreover, in proceeding eastward, in nearly the same parallel, 70 leagues farther, the water was found to be of ocean temperature; so that, on the whole, there was a *zone* of cold water, of 180 leagues, occupying a part of the ordinary place of the Gulf-stream! For Captain Beaufort, in Aug. 1809, (*i. e.* the preceding year), found a temperature of 76° to 79°, or 8° to 11°, *above* ocean temperature, within 40 miles, and that to the *northward* of the place where the packet had 60° in May, or ocean temperature.

Again, Captain Peter Bell, of Philadelphia, in his way from that place to Liverpool, in the beginning of *October*, found an equal temperature, numerically, as on his return in *January;* that is, 56°, which

was about 4° or 5° *above* ocean temperature, in January, and about as much *below* it in October; and this was exactly where Captain Beaufort found 76 in August, or 8° or 9° above it[1].

There can scarcely be a doubt that this water had been cooled by ice drifting from the northward into the stream; this quarter being precisely in its track southward; that is, between the longitudes of 45° and 56°, for they appear to be brought through the Strait of *Belle Isle*, as well as along the eastern side of Newfoundland[2].

Applying this to the circumstance of the cold water, adjacent to the line of the above-mentioned traverses, it may easily be understood, that nothing but the agency of *ice* could reduce the ocean water to 36°, in the parallel of 41°, in the month of March; when about 58° might have been expected. And although the ice might be dissolved, yet a degree of cold would remain.

The exceeding coldness of the counter-current,

[1] In effect, the temperatures reported in different years, between the parallels of 40° and 45°; and the meridians of 40° and 50°, vary more than in any other place, in this region.

[2] The Ice Islands are brought from Baffin's Bay and Greenland by the southerly currents, and have been found dispersed from longitudes 46° to 56°, between the parallels of 48° and 40°; and as some of them come through the Strait of Belle Isle, it is probable that they may be found as far west as Cape Breton. The Author has not heard of any farther to the eastward than long. 46°. Some of vast size, but in a rapid state of decay, have been seen in lat. $40\frac{3}{4}$°, at Midsummer; but it is improbable that any of them should long remain unmelted in the warm water of the Gulf-stream. They have been seen from April to October.

which runs to the south, along the coast of America, opposite to the Chesapeake and Delaware, may probably be owing to a like cause.

There are yet four more examples of Traverses to be examined.—These were kept apart from the former, which, being nearly in the same position, and having a close connexion with each other, in point of circumstances, gave strength to the general result, by being considered together. The traverses in question, although more dispersed, in point of local position, are individually as conclusive as the former, in respect of the parts to which they refer. One of these, also, is by Mr. Napier; a second by Mr. B—— ; a third is from the Maidstone frigate; and the fourth from Captain Pell of the Menai. The two latter, from their relative position to the before-mentioned five of Mr. Napier and of Mr. B——, may, with propriety, follow next in order.

TRAVERSE F.—*The Maidstone* crossed the Gulf-stream at about a degree and half of longitude to the westward of Mr. Napier's western traverse, and in the month of June, 1815. [CHART V.]

The northern extreme of the warm water, was found at 73 miles to the northward of the *central line* of the Gulf-stream, and in latitude 39° 35′, which is far *within* all the others; that of Mr. Napier, in Feb. 1820, excepted.[1] But southward it extended *beyond* all the others, that of May,

[1] They had noticed a strong *rippling* at about 12 or 13 miles before the first notice of warm water.

1820, (B) excepted. Its breadth was two hundred and seventy miles; and with a high temperature throughout, for the season: *i. e.* 76 to 78 degrees; or 10° to 11° above ocean temperature. The warm water terminated southward in 35° 6′.

TRAVERSE G.—*The Menai* frigate, Captain Pell, in her course northward from *Bermudas*, in July, 1815. The Menai entered the track of the *Maidstone*, at the point where she had quitted the warm water, in her way southward, (35° 6′,) and traced it back, without any indication of warm water, but with a very slow north-easterly current, to lat. 37° 15′, where, on the 18th of July, she first experienced a temperature of 74°; or 4° to 5° above ocean temperature. Thence, from the state of the winds, she was compelled to cross the stream in a north-easterly direction, (or only 30° wide of the course of the stream,) to lat. 39° 50′, in long. 62° 39′; by which she crossed, obliquely, all the five before-mentioned traverses of Messrs. Napier and B——; besides having traced back the southern *half* of the Maidstone's.

On the 19th July they were in lat. 38° 43′. The current had ran about E.N.E. 26 miles in the 24 hours, and the temperature of the sea had increased but little: and on the succeeding day, the 20th, and last day of being in the stream, the current ran between E. by N. and E.N.E. 48 miles. This was the *strongest* part of the *current*, and the *highest temperature*, that is 81°, or 13° above ocean tem-

perature. Beyond this station (which was in lat. 39° 50′, long. 62° 39′), there was no indication of current, nor any notice of warm water; for on the next day (21st July), in about lat. 40° 45′, the temperature was 70°, or only 2° above ocean temperature. (*Chart* V.)

However, as the temperature had been 81° at noon, on the preceding day, and was then (July 21) *somewhat above* ocean temperature, it is probable that the *Gulf-water* extended beyond the place, where the temperature of 81° was found; on a supposition, founded on experience of other parts of the stream; that is, that the high temperatures never extend to the very borders, but gradually diminish; and therefore, that warm water, although of a diminished temperature, extended a considerable way into the *run* of the 21st, which was of 61 miles: perhaps to lat. 40° 20′, or 40° 30′. But, unfortunately, there is no mark for the time, when the ship left the warm water, any more than when she entered it; nor, of course, any *data* for the breadth of the warm water. Captain Pell, however, estimates the breadth of the *stream* at 141 miles, and was probably correct.

Traverse H.—Another, the *fourth of Mr. Napier's traverses*, was somewhat more than three degrees to the westward of his former ones, in May, 1821. It was made late in September, of the same year, and lies in the line of route between Boston and Bermudas. The breadth was 223 miles, in a direction nearly at right angles with

the course of the stream. Its extent to the northward of the central line was only one-third of its length, two-thirds being to the southward of it.

Its temperature was the highest of all the traverses; it being in the season of nearly the highest temperature of the water in the Gulf of Mexico; (as that of Feb. 1820, may be taken as the lowest;) and accordingly the temperature of September was $88\frac{1}{2}^\circ$ at *maximum*; that of February 67°; or above ocean temperature respectively, $12\frac{1}{2}^\circ$ and $9\frac{1}{2}^\circ$.

The current was south-easterly throughout the whole traverse[1], as will be found to have been also the case on the 12th and 13th of the month of March preceding; but so many examples of E. by N. current at other times in the southern tract of the line of traverse, show that the S.E. current is not constant, although, probably, often recurring. More will be said on this subject in the next article.

I.—*Another traverse*, in March, 1821, (the third of Mr. B.—'s and the last to be considered,) is not directly across the stream, but, like Captain Pell's, zigzags across the foregoing one, occasioned by an adverse wind. Although this does not possess the advantages that are commonly to be derived from a more direct traverse, yet it affords an important notice respecting the course of the stream. For nearly seventy leagues the route lay

[1] The last eight or nine hours of the warm water might possibly have been *counter-current*. In this and others of the traverses one finds the temperature *decrease* going southward and afterwards *increase* again.

between E. by N. and E.N.E. along the middle of it, between longitudes 65° and 69°. The current, during this route, ran to the E.S.E. at the rate of 64 miles per day; agreeing, in a general way, with the just-mentioned traverse of Mr. Napier, in the same place.

As the warm water of this traverse terminated short of the parallel of 39°, in longitude 65°, and *very cold water* succeeded northward [1], one is led to conclude, combining this information with that of Mr. Napier, that the body of the Gulf-stream, in the months of March and September, of 1821, had a general south-easterly direction in that quarter of it; although throughout the month of May, of the same year, the warm water reached beyond 40½° generally, about this meridian.

It may be observed, in Captain Tozer's chart of his traverses, that, in September of that year, he experienced *no* current to the northward of 38¾°. It is possible that the warm water might not, at that time, have extended any farther northward in the line of his track, than in those of Messrs. Napier and B—; which, as has been said, was 39° 10′.

The high temperature of the water, which formed the just mentioned south-easterly currents, fur-

[1] The registry of the temperature goes on to the N. by W. In lat. 39½°, from 71°, it was reduced to 44°. In 40¾° it was 36° only, and in 41° 10°, the same.

Near the place of the *first* 36°, Captain Billings, in 1791, had 75° in September, or 6° to 7° *above* ocean temperature.

nishes a proof that it could be no other than *Gulf-water;* precluding the idea of its being a counter current from the northward; for the temperatures were from 77° to 80½° in September; 72° to 74°, in March; that is, from 9 to 12 degrees above ocean temperature. And it may be asked, how could a south-easterly current of warm-water have taken place in the positions occupied by Mr. Napier and Mr. B——, respectively, (that is, in the parallels of 38½° and 39°, and to the south-eastward of St. George's Bank,) but by the Gulf-stream having *previously ascended* to a *higher parallel* than 38½° and 39°, and in fact, having come up to the southern edge of St. George's Bank?

The bending of the stream to the S. of E. had been observed by the Nantucket whalers, according to Dr. Franklin. They say, "South of St. George's Bank it (the Gulf-stream) comes up to lat. 39°, and runs *east by south*, at the rate of 70 miles in the 24 hours." This appears to agree with the reports of Messrs. Napier and B—— ; and since then, it appears on the whole, that the border of the stream advances to the southern edge of the bank only *at times*, may it not be, that it is *at those times only* that an E.S.E. or S.E. current prevails? It is morally certain, that it could not have prevailed when Mr. Napier found no warm water to the north of 37°, in his way from New York to the south-eastward: for in order to its taking place, it must first have ran to the N.E. from his station in 37°; and then S.E. to those of Messrs. Napier and B——. And much the same

may be said of Captain Pell's observations near the Chesapeake.

The space within which the E.S.E. current of Mr. B—— prevailed, is entirely *new ground* to the Author, no one observation of the currents within it having ever come to his knowledge.

But there is an E.S.E. current reported in a different place, farther to the eastward, and which it is difficult to account for. It appears more in the character of an *anomaly*, because the regular Gulf-currents have been found there by Captains Rodd and Pell.

Sir Philip Broke cruised, during three weeks, in parts of October and November, 1811, between the parallels of 38° 30′, and 40° 30′; and long. 60° and 63°; and, consequently, within the usual bounds of the Gulf-stream, frequently crossing the stream into *ocean water* on either side. He found the currents setting *constantly* to the *E.S.E.*, but irregular in respect of velocity. It was never less than 25 miles per 24 hours, often 30, and several times 50. The weather commonly stormy, the winds from N.W., S.W., and south.

Now, the space within which the traverses of Captain Tozer lay was *adjacent to*, and *between*, the places of the just mentioned south-easterly currents, reported by Sir P. Broke on the one hand, and Messrs. Napier and B—— on the other; and yet no traces of such currents appeared during the intervals in which Captain Tozer crossed the Gulf-stream seventeen times in the course of three years; and in every month of the several years,

save July and December. There was, indeed, one single instance of a current to the S. of E., which was E $\frac{1}{2}$ S. 30 miles, in lat. 38$\frac{1}{2}$°. Captain Tozer even crossed the stream on the very days[1] when Mr. Napier experienced the S.E current, but had *no* current, save on one particular day, and that a N.W. one.

We must not, however, take the result of any single examples *too strictly*. One example alone is given for each day: that day's run may have been very long, and the current may have existed only during a part of it, or two opposite currents may have wholly or partially *neutralized* each other. But the number of examples furnished by the same person, and in the same place, adds great weight to the authority of Captain Tozer. And there are besides six other traverses, by other persons, all tending to the same point.

One can hardly regard the E.S.E. current noticed by Sir P. Broke, as any other than an *anomaly*, such as take place at times in all streams of current, and which have been repeatedly found to exist in the *Equatorial* current, which, after the Gulf-stream, is perhaps one of the most regular and constant.

The popular error of conducting the Gulf-stream across the Atlantic, in an E.S.E. direction, and describing it to fall on the Canary Islands, and on the coast of Africa, most probably arose from its

[1] Mr. Napier, Sept. 22, 24; Captain Tozer, Sept. 23, 24; between latitudes 36$\frac{1}{2}$° and 39°.

having been often observed to turn off from the Banks of St. George and Nantucket in that direction. In effect, they decided on the *whole* from the knowledge of a part; and a S.E. current actually falling on the said islands and continent, although a distinct thing, it being a current originating in *our* parallels,) favoured the supposition. At that time the different temperatures of the sea water had not been observed; otherwise the *coldness* of this current might have prevented the mistake.

To return to the traverse (I.I.) *of Mr. B*——, in March, 1821. Another important notice communicated by it is the proof of a *counter current of warm water,* of 13 to 21 miles, running to the westward, and along the south side of the main stream, between the parallels of 35° and 36°. This is the second example of the same kind, Captain Livingston having experienced a like current in latitude 39°, and between the meridians of 55° and 62½° W.[1]

To the above statements may be added the following observations respecting the extent of the warm water northward, in this quarter.

Dr. Franklin learnt from the Nantucket whalers that the edge of the Gulf-stream comes up to lat. 41½° in the meridian of Sable Island (or about 60° long.) But it appears by the journal of the Eliza packet, that late in April, 1810, in that longitude, and in latitude 42° 15′, the temperature was 64°,

[1] This is noticed more particularly hereafter.

or 5° above ocean temperature; a temperature belonging rather to 35° at that season. And Colonel Williams says, as already noticed, that *whirlpools*, occasioned by the stream, are seen in lat. 42°, and in a position near to, or at, the edge of the Sable Bank. So that, at times, the Gulf-water *may* have reached a higher parallel than we are yet aware of, and may have produced that great steepness of the edges of the banks that extend along the American coast.

RESULTS OF THE PRECEDING INQUIRIES AND EXPERIMENTS.

I come now to the most important and ultimate point in the present inquiry, the subject of the CURRENTS of the Gulf-water, in that section of the stream which has been so long under consideration, and towards which the examination of the position and extent of the warm water was a necessary preliminary.

It is unfortunate that there are no means of knowing, in the present state of things, what proportion of the warm water belongs to the stream itself, what to counter currents, in places where they prevail, or what to the still water.

One may, however, consider it probable that, in February, 1820, when the whole breadth of the warm water was confined to 140 miles, that the great body of it was in motion, as constituting the *proper Gulf-stream;* more particularly as Captain Pell, in crossing the stream in the same place, in

July, 1815, reckoned it at 140 miles; and this appears to have been the result of his observations on the current itself, and not on the warm water. But it cannot be readily supposed, that when the breadth of the warm water increases suddenly, as from 186 to 240 miles, in the course of ten days, and again decreases from 248 to 186, in about a week, that the *body of the stream* accommodates itself to those changes. One would rather regard it as an *offset*, or temporary overflowing; but, at all events, as occasioned by a *larger* quantity of Gulf-water being brought forward in a given time; and which, doubtless, in a great degree, increases the body of running water, but not in any degree proportioned to the increase of breadth of the warm water [1].

It will be recollected that *south-easterly* currents have been described, in great detail, when speaking of the traverses of Messrs. Napier and B——, in that part of the stream towards the Bank of St. George, &c.; a quarter, concerning which we have no knowledge beyond what these facts themselves convey; but which must be regarded as bearing the stamp of high authority.

I am in possession of a very considerable number of examples of the direction and rate of the

[1] It is well known that the stream is about twice as rapid at certain seasons as at others.

When rivers overflow their banks, the floods produced have little or no motion; and the river itself slackens its motion, by being relieved from a portion of its superabundant waters. The *levels*, in such cases, do not, of course, *admit* of counter currents.

stream; they are from various authorities; but most of them from Captain Tozer, Captain Rodd, Captain Pell, Mr. Napier, and Mr. B——. They consist of two kinds; the one from tracks made *along*, or in the direction, of the stream; the other *across* it, and of which there is the greatest number. The results of the rates of the two classes are very different; since all the parts of any given section of the stream, do not, any more than those of a river, run with an equal degree of velocity; the rate obtained in *crossing* will, therefore, be a mean of all the different rates across that section. But *along* any rapid part of the stream, which is the line sought by those who navigate it, the rate of the current will be found considerably greater than in the other.

The chart of Captain Tozer (as I have said before), contains no less than seventeen tracks across the stream, made in the years 1819, 1820, and 1821, in the usual line between *Bermudas* and *Halifax*, and in every month, save July and December. He found only one example of easterly current to the northward of lat. 41°, and not one farther southward than 37°; about which parallel the stream had, most commonly, a strong tendency to the *southward* of east; as, indeed, appears to be the case, generally, throughout the whole extent of the southern border of it: probably the commencement of that *overflowing*, to which, no doubt, may be ascribed the great extent of warm water to the southward. The bulk of Captain Tozer's examples of easterly (or rather north-east-

erly) current, was comprised between the parallels of 37° and $40\frac{1}{2}$°, and the most rapid part of the current was between 38° and 39°[1].

This document is particularly valuable, as containing so many repeated experiments nearly in the same place and by the same person. It also has a general agreement with the observations made by other persons, as well *across* as *through* the stream, in and about the same quarter.

From these authorities, collectively, the rate of the currents of the Gulf-stream, in that section of it through which lies the usual route between Bermudas and Halifax, may be satisfactorily approximated, as that between the Chesapeake and the section in question have already been. (page 169.)

There are, in all, eighteen examples of the rate *across* the stream, and these vary from 50 to 19 miles per 24 hours; but are, at a mean, $35\frac{1}{2}$. Ordinarily, the examples are from 30 to 36[2]. Of the eighteen, ten are by Captain Tozer[3]; the others

Mr. Downie observes, that the Gulf-stream runs between 37° and 40°, between long. 60° and 69°. Our remark applies to 64°, nearly his mean.

[2] The rates of 67 and 64 miles, experienced by Captain Tozer and by Mr. B——, respectively, during their traverses, were during *whole days*, on which the winds, not blowing across the current, compelled them to thread it.

[3] As seventeen traverses of Captain Tozer are previously mentioned, and no more than ten made use of in the calculation, it is proper to state, that only 10 of them contained examples that were applicable to the *crossings*. Some of the others apply to the *course* of the stream only; being the results of days' works along or through it, and not across.

The

from Captain Pell, Messrs. Napier and B——, &c. The ten of Captain Tozer gave a mean of $39\frac{1}{3}$; the eight others $30\frac{1}{2}$: general mean $35\frac{1}{2}$. The examples of the rate, *along* or *through* the stream, and which are presumed to have been generally made through a rapid part of it, give a mean rate of $55\frac{1}{2}$ miles, or about one-third greater than the rate across; but the observations were chiefly made in the summer season, when the current is usually at its greatest strength. There are, however, examples of 64° in March and 48° in April.

The winter examples, along the stream, are few, as there are few reports from his Majesty's ships at that season; and the examples are generally furnished by them. Hence, as the rate *across* is the mean of *all seasons*, and that *along* at the season of the *high rate* alone, this latter will of course bear too high a proportion to the former, when taken respectively at $55\frac{1}{2}$° and $35\frac{1}{2}$°; but I know of no rule by which it can be corrected.

I shall now offer some general Remarks on the above curious documents, respecting the temperature and extent of the Gulf-water, and on the direction and velocity of the currents; premising

The rate of the stream at 100 leagues farther to the eastward, *i. e.* in long. 58° and 59°, in August, was 54 to 59 miles, and its direction more northwardly; but it may be doubted, whether the surface of the stream might not have continued in a disturbed state, owing to the hurricane which had recently prevailed.

At 300 leagues, the rate was from 30 to 33 miles, according to the observations of three different persons, in August and September of four different years.

that these remarks are intended to apply only to that part of the stream across which the above traverses were made; and which is comprised within the space of about $4\frac{1}{2}$ degrees of longitude. But it may be conceived that this *specimen*, taken at a point 500 miles beyond the place of its entrance into the Atlantic at *large*, may be sufficient to convey a general idea of the course and nature of the stream; more especially as it is found running in the same general line of direction (although, of course, with a diminished rate of motion and temperature, and an extended breadth,) at a point many leagues farther to the eastward.

It may be remarked,—

First, That the *change of position* and *breadth* of the column of warm water, from time to time, is abundantly proved by the traverses of Mr. Napier and of Mr. B——, particularly by those which were made nearly in the *same place*, considered in the view of general hydrography. They show that the *northern* limit of the warm water varies *more than a degree and half of latitude*; and the *southern* limit about *two degrees and a quarter*; and that the breadth of the columns of warm water varied in breadth from 140 to 320 miles, with intermediate ones of 186, 223, 240, 248, and 270.

But nothing appears from these great variations to warrant a conclusion that they have any immediate reference to particular seasons; as the warm water in May, 1820, was the widest of all, and that of May, 1821, was amongst the narrowest. It may be supposed that the degree of velocity of the

current, through the Strait of Florida, must determine the point; as the strongest current must of course bring a greater volume of warm water into the Atlantic, in a given time.

SECONDLY; That the existence of warm water does not necessarily indicate the presence of the Gulf-stream, more especially to the southward of lat. 37° (in the aforesaid long. of 63° to 65°), but is rather to be regarded as an overflowing, or deposit, of superabundant warm water, like a swollen river, or may form a counter current; although, on the other hand, the Gulf-stream itself must necessarily be composed of warm water; and that the southern part of the stream, as may be seen by a reference to the Chart, has a manifest tendency to the S.E., which may be the *immediate cause* of the greater extension of the warm water to the southward, than to the opposite quarter. But as this S.E. tendency must also have *its* cause, it may perhaps be looked for partly at the place of the ordinary termination, near the Azores, partly at the place of its outlet in the Strait of Florida. For, in the former case, its bend round from east, northerly, to E.S.E. and S.E., must influence the direction of its southern parts, *progressively*, as the influence extends westward; and, in the latter case, the natural extension of the stream laterally, shut up on the land side, can take place only on the side toward the ocean, that is, the southern side.

THIRDLY; That, in Feb. 1820, and in May, 1821, when the warm water was comprised within the narrowest limits on record, (*i. e.* 140 and 186

miles) it occupied, generally, the *northern* part of the space which is occupied by the warm water at large, when at its greatest extent of breadth. From whence it would seem as if there was, *permanently*, a body of warm water to the north, whilst the southern was only *casual;* and that it might be inferred, that the northern course was the one which the Gulf-stream more commonly took.

FOURTHLY; That, in the traverses generally, the *warmest* water is found to the north of their *respective centres*, and that *considerably;* as if indicating the track of the *strongest part of the stream.* This seems to be exemplified by the observations of Captain Pell, he experiencing the *strongest current*, with the *highest temperature*, and that, also, to the *northward;* and also by Mr. Napier's Remarks on the different state of the sea, under different temperatures.

FIFTHLY; That *veins* of *cold* or *colder* water have been found, within the body of the warm water; and although the fact may not lead to any conclusion, yet is curious; and is similar to what has been found to take place in the *Lagullas* Current.

SIXTHLY; That although the ancient charts, generally, as well as many of the modern ones, describe the Gulf-stream to take an E.S.E. or more southwardly course, across the Atlantic, and to fall on the Canary Islands; yet it is certain, that this does not take place, because it is found running on a course of more than a point to the northward of east, to more than ninety leagues to the eastward of the Great Bank of Newfoundland,

and between the parallels of 41° and 44°. The error seems to have arisen from often observing that, from whatsoever causes it may proceed, the course of the stream has, in particular places, had a S.E. or E.S.E. direction. But it has appeared by the numerous examples set forth, that this course does not extend even to the line of route between Bermudas and Halifax. towards the *Azores*, indeed, it turns to the S.E. and south, and afterwards to the S.W., forming a *counter current*. And it *has happened*, that, pursuing its east-northerly course, it has reached the coasts of Europe; of which more particulars will be given in the sequel.

SEVENTHLY, and lastly; that, although examples of strong easterly currents have been found to the northward of lat. 40°, yet they are rare; and that southward there were none whatsoever observed beyond 37° (between the longitudes of 63° and 65°), in the course of seventeen traverses, made in three different years. Also, that the generality of the examples of strong easterly or north-easterly currents were comprised between the parallels of $37\frac{1}{2}$° and 40°; and that the line of the *strongest* current is between lat. $38\frac{1}{2}$° and 39°. That this seems to accord with the space within which are comprised the *narrowest* columns of warm water that have yet been remarked, so that one cannot help regarding the space between the above-mentioned parallels of $37\frac{1}{2}$° and 40°, as being the most common course of the Gulf-stream.

About the parallels of $38\frac{1}{2}$° and 39° then, between the longitudes of 63° and 65°, one would expect, at

ordinary times, to find the Gulf-stream in ***strength,*** and its general course, through the Atlantic at large, from W. by S. $\frac{1}{4}$S. to E. by N. $\frac{1}{4}$N.[1]

But enough has been shown to induce a belief that there are in this, as in all other currents, great temporary changes, both in its line of direction and velocity.

It has been said above, that the eastern and greater part of the GULF-STREAM is utterly unknown, in respect of its *detail.* Captain Rodd, as we have said, was driven out of it to the northward, as shown in page 202. It is probable that the hurricane had disturbed the regular course of the stream; for when he again found the easterly current in lat. $40\frac{1}{2}°$, and long. between 60° and 57°, its direction was nearly *north-east.* And after this, in the same latitude, and between it and lat. 42°, long. 57°, he experienced a *northerly* current.

Captain Rodd must now be considered, as being beyond the northern edge of the stream; and from hence, in his course to the eastward, from long. 55° to 45°, between the parallels of $43\frac{1}{2}$ and 43°, in the course of five days, he successively experienced currents from all the four quarters; from 10 to 42 miles per day.

A doubt arises concerning the place occupied by the great body of the stream, at the date of either of the observations; since they give no more than a *single point* in it. No doubt of this

[1] It is possible that it may have varied its course intermediately, as Captain Rodd found it more northerly in longitude 37°.

kind arises, respecting its having been to the *southward* of Captain Rodd, until his re-entering it; since he was driven out of it *to the northward;* and it seems equally certain that Captain Beaufort had it to the southward of him, as he so soon afterward got out of it to the northward. The observations on board the Queen, in lat. 41°, by its southwardly position, only furnishes a *presumption* of its being towards the southern edge of the stream.

The stream doubtless had expanded very much in its course through the Atlantic, from long. 64°, in which it was estimated at 140 miles in breadth, by Captain Pell; but I should doubt its having spread from 140 to 240.

The circumstance of the same kind of current, both in direction and velocity, being experienced on board the Queen, and by Captain Livingston, in different years, in the same place; that is lat. $39\frac{1}{2}$, long. $51\frac{1}{2}$; and traced by the former eastward, 180 leagues, to the place of observation, might lead one to imagine that this was its ordinary course.

It has been mentioned that Captain Livingston experienced, in the same voyage, westerly or counter currents, of warm water, through a course of more than 100 leagues, between the parallels of 38° 50′ and 39° 20′; and between the meridians of 55° and $62\frac{1}{2}$°. The rate was from 26 to 31 miles per day, and temperature 77° to 79° (in the beginning of September) answering to that of the Gulf-stream itself; and consequently composed of *its* water, re-

cently diffused. The temperature also decreased, as he went *eastward*, to the place where he, as well as H. M. S. Queen, came again into a *strong easterly* current; *i. e.* the Gulf-stream, as the same current continued 180 leagues farther to the eastward.

It cannot well be doubted then, that Captain Livingston, when in the counter current, was on the *south* of the great body of the Gulf-stream. But his position being then as high as 39°, when about long. 62½°, throws the place of the Gulf-stream uncommonly high, in point of parallel. Within the same space, nearly, the Queen had experienced, in a former year, S.E. and southerly currents; and she also must have been on the *south* of the stream.

Here we are under the obvious necessity of supposing the Gulf-stream to have, at that time, attained its highest point of northerly position. But it is difficult to trace, in idea, the intermediate course of the stream, from Captain Livingston's station in the counter current, in long. 62½°, and the place, where he and the ship Queen came *again* into the Gulf-stream, unless we are to suppose either a *bend* in its course, or a *sudden expansion.*

Whether the tail of the Bank of Newfoundland, may have effect in *turning* the stream to the south, or of *dividing* it, may be a question. Certain it is, that we have no correct information concerning *its form:* and currents are turned aside by banks on which the water is many times as deep.

Concerning the bending of the Gulf-stream to the S.E. and S., near the Azores, and thence to the

S.W.; the cause has not been explained. Whether there be *banks* or *ledges*, at present unknown to us, extending from the *Azores*, in the direction of that chain, towards the Bank of Newfoundland, that turn it from its long continued east-northerly course to the S.E.: whether the currents from Greenland and Davis's Strait, which are well known to exist, may, by their junction with it, give it an *obliquity* of course; or whether it be the general motion of the Atlantic waters to the S.W., occasioned by the trade-wind, which draws the contiguous waters on the north after them: certain it is, that the stream does so turn; and that, at times, water of 79°, or 12° above ocean temperature, has been found in lat. $33\frac{1}{2}$° and 34°, at only six degrees to the west of the meridian of Corvo. The subject of the *Arctic* Current, being of importance to the present question, will be entered on, and discussed at large, at the end of the present section.

Such are the principal notices, concerning the *ordinary* course of this remarkable stream, that have come to the knowledge of the Author; for although the Gulf-stream has been navigated by Europeans, during more than three centuries, yet materials for the developement of its nature and extent have in few instances been collected; and even these studied with little effect; otherwise it would have been impossible that, almost down to the present time, its general course through the Atlantic should have been represented to be E.S.E. and extending to the Cape Verde Islands; or that

its warm temperature should have been unnoticed till about the year 1775.

The want of simultaneous observations is an incurable defect. By this we are kept in ignorance of the state of things in every other quarter, save the one in which our *own* observation was made. All, therefore, that could be done, was, faithfully and carefully to place the observations on record, in such a mode as to render them the most useful; and to wait until the fulness of time shall, by adding a sufficient number of observations to those already collected, unfold the secrets which are now withheld from us.

There are still other particulars exceedingly curious, and some of them no less useful, to be made known respecting the Gulf-stream; as, its *Counter* currents, emanating from the *main* stream, a knowledge of which is essential to navigation; but to which the paucity of materials is a formidable obstacle. Also, the vast expansion of the warm water, deposited in the centre of the Atlantic; which, by heating the incumbent atmosphere, occasions frequent, and sometimes fatal, storms. Also, the progress of the warm water; and, of course, of the mass, or at least a large portion, of the Gulf-stream to the shores of Europe; which actually happened in 1776, and again in the present year, 1822. Into these particulars, I shall inquire more fully, after discussing the subject of the *Arctic* or *Greenland* Current, which has been mentioned as an *adjunct* of the *Gulf-stream*.

7.—The ARCTIC or COLD CURRENT, which unites with the Gulf-stream, near the Grand Bank of Newfoundland.

The Currents from Davis's Strait and Greenland, although well known to exist separately, at the outset, are not well discriminated in respect of their course and description. It is only known that, at times, *a* current runs to the S.W. along the eastern coast of Old Greenland; and another to the *eastward of south*, along the coast of Labrador; and thence along the east side of Newfoundland, (detaching a branch through the Strait of *Belle Isle*,) and finally approaching the Gulf-stream. Whether these form a junction by the way, or pass the parallel of Newfoundland, in separate streams, is not known to the Author; through the want of a sufficient number of observations: nor, indeed, does the question seem to have been at all considered hitherto. It seems to have been taken for granted that there was a single stream only; without any regard to the *great breadth*, which it must of necessity have, if the current along the coast, and that which has been experienced to the eastward of the Great Bank, be parts of the same stream: that is, at least, 100 leagues.

The current which passes along the coast, is obvious to every one, and requires no proof or elucidation, save in respect of its breadth. That to the eastward, is also well known from Journals, in re-

R 2

spect of the position of its main body and its eastern border; but its extent, westward, is as little known as that of the *coast current* eastward. Here are the details.

Captain Beaufort, of his Majesty's navy, in the beginning of October, 1808, when at about 90 leagues, E. by S., from Cape Race (lat. $45\frac{3}{4}°$, long. $46\frac{1}{2}°$) and nearly midway between the Outer and Grand Banks of Newfoundland, (according to the Charts, he was, however, in 116 fathoms, *fine sand and oaze*,) and found a current running south, 11 miles per day, and saw ice islands.

This position unquestionably places him in the *Arctic Current*. The following Journals will show that it extends to a much greater distance, eastward.

A ship, name and commander unknown, crossed the same southerly current, at about 25 leagues to the southward of Captain Beaufort's track, in the end of May 1814: and found, not only a southerly current, but *very cold* water, through a breadth of more than 50 leagues directly across, from longitude 44° to 48°, between the parallels of $44\frac{1}{2}°$, and $45\frac{1}{2}°$. The rate of the current was from 15 to 20 miles per day; and the temperatures, in places, so low as 16 to 17 degrees below ocean temperature. From a temperature of 62°, and an E.N.E. current of 30 miles per day, it fell, in the course of a few leagues, to 56° and 55°; and the current changed to S.W., and subsequently to south. In the course of eighteen leagues, the temperature became 43°, or 17° below

ocean temperature, and at 30 leagues, was still 44°. At 55 leagues, (in long. 48°) they supposed themselves near the eastern edge of the Great Bank, as the temperature fell to 39°. No details are given beyond that point: and no current is *mentioned* westward, beyond longitude 46°.

A second ship, the *Chesterfield* packet, at the end of June, 1790, crossed the same cold water, and in the same general longitude with the former ship, but at about 17 leagues farther to the southward, and 42 leagues to the southward of Captain Beaufort. The temperatures were from 57° to 49°, or 5 to 13 degrees *below* ocean temperature of that season; which was a month farther advanced towards summer heat, than that experienced by the former ship. But, nevertheless, I should refer the advanced warmth to being nearer the border of the Gulf-stream; or perhaps to an admixture of its waters with those of the Arctic Current. For the difference is too great for a month's advance of season.

The breadth of cold water was 40 leagues, or less; and did not extend so far eastward as the former by 40 miles. But, as may be supposed of *that*, it probably extended westward, over a part of the Great Bank: but the cold produced by the Bank itself, precludes any attempt to trace, or to estimate, the different degrees of cold arising from the Bank and from the current, respectively.

The third case was that of a brig, Captain Dayment, which was caught in the ice, and drifted with it, to the S.E. She left the N.E. coast of Newfoundland on the 19th of January, 1818, and,

in the evening of the same day, saw several islands of ice. Next morning, at sun-rise, the vessel was closely enveloped in ice, without any means of escape visible from the mast-head. The ice consisted of fields 14 feet above the water, intermixed with a vast number of very large icebergs[1]. They were carried in this manner no less than 29 days, to the S.E., and to the lat. of 44° 37′, and 300 miles E.S.E. of Cape Race; or to about long. 46°; which would place them within the eastern border of the cold water, observed in the Chesterfield, and at about 20 leagues S. by E. from Captain Beaufort's station, in October, 1808.

On the morning of the 20th January, when first *beset*, they had probably ran 100 miles to the eastward, from Greenspond, on the N.E. coast, in latitude 49° 5′. From thence, to the place of their escape from the ice, the distance is about 300 miles, in a direction nearly S.E. ; which allows ten miles *per* day ; but the master says that, on the first fifteen days they were carried only 60 miles, or only 4 miles each day; whence the inference is, that they were carried *faster on other days:* and therefore *not directly* to the S.E.

There is, however, a direct proof of a set to the S.E., on the *whole of their drift*, by the position in which they were left. But as they had no chronometers, great doubt may be entertained concerning the quantity of *easting ;* and it seems

[1] A copy of the original paragraph, from which these particulars are given, will be found in the Appendix hereafter.—Ed.

likely that the current was more *southerly* than *easterly:* and consequently, that they were not so far as 300 miles to the eastward of the meridian of Cape Race.

The authorities, collectively, are satisfactory in respect of the *general* course of the Arctic Current; and of the eastern border of it. For, by one ship it was not found to the eastward of long. 44°, in lat. $44\frac{3}{4}$°; and by another, in long. 45°, in lat. $44\frac{1}{2}$°. Both ships came from the eastward, with the sea at ocean temperature nearly, until one of them just dipped within the northern verge of the Gulf-stream; and found an E.N.E. current of 30 miles *per* day: and afterwards came suddenly into cold water, and a southerly current.

Now the northern edge of the Gulf-stream has been found as high as latitude 44°, by Captain Beaufort; and in lat. 45°, by Colonel Williams; in the longitudes in which the cold water and southerly currents have been found, as above related: and the E.N.E. current of thirty miles per day, experienced by the *May* ship, accorded in position with the line of current experienced by Captain Beaufort. Therefore, the Arctic Current should, at *that time*, have joined the Gulf-stream in about the same parallel in which Captain B. found the northern edge of it, in August, 1808. But as that stream varies the position of its borders, in respect of parallel, it must follow that the place of junction of the two streams must vary also, and often take place farther to the southward: and thus verify the remark, " that the temperatures reported

in different years, between the parallels of 40° and 45°, and the meridians of 40° and 50°, vary more than in any other part of this region." This, no doubt, arises from the above-mentioned changes. At one time the *warm*, at another the *cold*, current, occupies the space exclusively; and at others, the waters of both are intermixed, in different degrees of proportion.

Still, however, a doubt remains whether there be one collective stream, extending from the eastern extremity of the cold water, found in long. 44°, to the coast of Newfoundland; or whether there be *two distinct streams*, which unite with the Gulf-stream. There is no doubt concerning the fact of the existence of southerly currents in both places; but what is the state of the intermediate space? The great bank of Newfoundland, by cooling the sea over it, renders ambiguous the examples of its temperature; otherwise some judgment might have been formed.

The most intelligent of the Newfoundland navigators, (according to my friend Sir John Duckworth,) suppose a single stream of current only; which, from Davis's Strait and Hudson's Bay, takes a S. by E. course along the eastern coast of Newfoundland, and joins the Gulf-stream in lat. 40° or 41°, long. 49°. That it runs at the rate of one mile and a half *per* hour, in summer, and increases to nearly $2\frac{1}{2}$ in autumn. That in May, the ice brought by it, is the most abundant on the coast. That a branch of it passes through the strait of *Belle Isle*, to the S.W., and joins the *out-*

fall of the St. Lawrence river; and another branch, or an eddy, passes round Cape Race, to the westward; rounding the Bays[1] in its course."

This statement appears to be *generally* true; bating the place of junction with the Gulf-stream: for that is disproved by the known fact, that the northern edge of that stream is commonly found at two degrees, or more, to the northward of 41° in that longitude.

Concerning the rate of the Arctic Current, I should conceive that it was taken much too high. The direction I should have supposed to have been more eastwardly than S. by E.

I certainly observed two distinct *streams* of ice, in May, 1757. If these belonged to two distinct currents, then we must suppose the eastern one to be that from Davis's Strait, &c., and the other from the eastern side of Old Greenland. But I have no means of placing these streams of ice on the chart.

Captain Parry, both in his way out and home, found a current of 10 to 12 miles *per* day, between the parallels of $57\frac{1}{3}°$ and $58\frac{2}{3}°$; and longitudes 39° and $40\frac{1}{2}°$. This may be taken for the southerly current noted by Captain Beaufort, and by the *May* ship: as that one by Captain Parry also, setting to the southward along the western shore of Davis's Strait, may be taken for the same current which afterwards runs along the eastern shore of Newfoundland.

[1] For an extract from Sir John Duckworth's letter, see note 1, page 30. The Ices from the Northern Seas have been already noticed in pages 90 to 95.

It has been said above (p. 243) that, if the two currents are only parts of one stream, that stream must be 100 leagues in breadth: but which therefore appears improbable. It must not be forgotten, that the *May* ship found *no* southerly currents, (or, indeed, currents of *any kind*,) to the westward of long. 46°; although the water was very cold, all the way to long. 48°, (the supposed edge of the *Great Bank*). Was, then, the space of about 86 miles, between longitudes 44° and 46°, the breadth of the *Eastern* Current? The termination of the Captain's observations *here* is accounted for, from his object having been merely the temperatures of the Gulf-stream.

One can scarcely suppose that so weak a current as 15 to 20 miles *per* day, would force the Gulf-stream, of more than 30, into a new line of direction, differing so greatly from its former course; considering also its vastly greater magnitude. It appears, also, that the junction takes place too far to the westward of the *bend*, to be admitted as the cause of it. To which may be added, that, at the séason of the greatest strength of the Gulf-stream, it came up to the parallel of 44°, or higher, at the place of junction.

But, when the Gulf-stream is weak, may not the Arctic Current affect it more than when it is strong? or then only [1]?

[1] Some additional and interesting remarks on this subject are given in the Appendix.—Ed.

8.—Of the COUNTER CURRENTS of the GULF-STREAM.

Concerning these Counter Currents, we possess *general* notices in abundance respecting the *eastern* part; but the *detail* is confined chiefly to the western part, and to the south of the Gulf-stream; for Captain Tozer, who crossed the stream so often, rarely found any westerly current on the north. Other Reports give the same conclusion.

The cause of this greater proportion of it being on the south, is probably owing to the bending of the great body of the stream to the southward, near the *Azores*, and enveloping the islands of Corvo and Flores; where, as we have already said, after it has passed to the southward of those isles, and spread a large proportion of its waters along the S.W. side of the chain of the Azores, the remainder, as far as the current is perceptible[1], takes a decided course to the W.S.W. and S.W.[2], and is traceable, in a general way, on this latter course, between the parallels of 35° and 37°, as far west as longitude 45°, but is there lost to our observation.

Dr. Franklin experienced this current, in considerable strength, in August, 1785, between the

[1] It is suspected, that there is very commonly a gentle, though imperceptible, motion of the Gulf water to the southward; otherwise it is difficult to account for the position of the weed.

[2] The commencement of the counter current.

parallels of 34° and 36°, all the way from the Azores, westward, until he entered the Gulf-stream, opposite to the entrance of the Chesapeake. As his *reckoning* includes the whole space between the Azores and the place of his entering the stream, it cannot be known what proportion of four degrees of *westerly set* (or 190 miles) was the effect of the counter current, but probably the greater part[1].

His M. S. *Pactolus*, in June, 1816, [see Chart. I.] experienced a S.W. current of 10 miles per day, to about latitude 36°, long. 42½°, but felt no other current in her way to Bermudas, until she came within 70 miles of that island; and then had a current of 13 miles per day, W.S.W. It is probable that the *counter* current, at that time, passed very far to the northward of the Pactolus's track.

The warm water of the Gulf-stream is known to extend, generally, southward, to lat. 35°, and even to 34°, in the quarter eastward of the meridian of 60°; the vast extent of space between this and the Gulf-stream itself, being the *recipient* of the *Gulf water*, arising as well from the *returning* water, as from the *overflowing* or *effusion* of the stream, during its eastern course, and probably of this latter, in the greatest proportion; as the water is of a higher temperature as we proceed westward, through the recipient, from having received the

[1] As the Doctor made this voyage in time of peace, in a ship navigated by persons who may be supposed to know how to profit by the counter current, and with fair winds generally, one may conclude that such a route was made as would be the most likely to secure the advantages of it.

Gulf water, at an earlier period. It seems not improbable then, that so vast a *depôt*, and continually augmented by fresh arrivals of water, should require a great breadth, in order to run off, as the motion is so gentle.

It may therefore be conceived that, the most *regular* and strongest line of counter current proceeds from about latitude $38\frac{1}{2}°$, in longitude $40°$, on a general W. by S. course, to the place which is pointed out by Captain Tozer's westerly currents, between $34\frac{1}{2}°$ and $35\frac{1}{2}°$ latitude, in longitude $65°$, as the course of the counter current of about 20 miles per day[1].

The Report of Mr. Downie carries us five degrees of longitude more to the eastward, or to long. 60°, lat. 36° to 37°. (that is, to the extent of his knowledge that way). He reports a south-westerly current *there*, and which harmonizes with the observations of Captain Tozer, and with those of Mr. B—, in lat. 35° to 36°, long. 69° to 70°, where that gentleman found a westerly current of *warm* water, running at the rate of 13 to 21 miles per day; and from whence a continuous current has been traced to the S.W. or W.S.W.

[1] A counter current of *warm water*, reported by Captain Livingston, in such a position, as to appear a kind of *anomaly*, in our present imperfect state of knowledge, has been already spoken of at large, in page 228, as being called for in that place; and to that we beg leave to refer. From the weight of authority, the fact cannot be questioned. It may be sufficient in this place, to state that the current, running W. by N. more than 100 leagues, occurred between the parallel of 38° 50′, and long. $62\frac{1}{2}°$, and lat. 39° 20′, long. 55°.

There can be little doubt, then, of the existence of the same stream, continuously, through the intermediate unexplored space, although no less than 320 leagues in extent; for, even in the failure of authorities, the circumstance of finding a similar current in the same general direction, as it left the long. of 40°, in lat. 38½°, affords a strong presumptive proof of the continuity of the stream throughout.

Sir Philip Broke informs us, that when cruising to the southward and eastward of Bermudas, in 1811 and 1812, there were strong currents running to the S.W., or W.S.W., and that he spoke with many vessels from the West Indies, Carolina, and Florida, going towards England, which had been driven from 10 to 12 degrees of longitude to the westward of their reckonings. And some, which were not advanced 500 miles on their way from Amelia Island, were half that distance out in their account of longitude. It was Sir Philip's idea, that "beyond the southern boundary of the Gulf-stream, from the Azores towards *Bermudas* and the *Bahamas*, there is a strong *set* to the S.W. or W.S.W.—[See note, pages 181, 2.] And he also observes that, beyond the northern border of the Gulf-stream, between 60° and 65° W., ships are frequently assailed by strong N.W. currents, or rather *eddies*, but that they do not always prevail.

The S.W. *or counter current* above-mentioned, in long. 69½°, has been traced through the whole space between that position and the outlet of the Gulf-stream from the Strait of Florida. And, indeed,

this is the portion of the counter current, the best known in detail. It runs in a direction opposite to the Gulf-stream, along its eastern border, and apparently brushing it, during its north-easterly course, along the shores of *Florida*, *Georgia*, and *Carolina*. It may be difficult to arrange this current under a proper denomination, as being partly *within* and partly *without* the region of trade-wind; so that it is partly made up of the returning waters of the Gulf-stream, and partly of the waters of the *drift* current of the trade-wind; and, accordingly, it increases in velocity, as it advances through the latter; running only 11 to 18 miles per day, opposite and near Cape Hatteras, but increases to 22 or 23, farther to the southward.

When this stream arrives opposite to the outfall of the Florida, or Gulf-stream, it turns to the south-east, along the outer side of the *Bahama Archipelago;* receiving into its body a large *offset* or branch of the Gulf-stream, which rounds the *Maternillo Bank*, on the one side, and on the other, continues to receive, as it advances, the drift-water of the N.E. trade-wind.

How far this stream may extend to the S.E., is not known to the Author; or in what manner it terminates; but it is known to be of considerable extent and force: since some who have passed through the Strait of Florida, with the intention of going through the *Windward* Passage, have found themselves in the meridian of the *Mona* Passage, or in that of the *Virgin Islands.*

With the exception of this stream, (which may be regarded as the *Stream current* of the *Western*

Atlantic), one may conclude, that a S.W., W.S.W. or westerly current, prevails generally over that part of the ocean, to the southward of the Gulf-stream, and to the westward of the meridian of 40° W; and southward to about the parallel of 20°. Beyond that parallel, the currents gradually point to the north of west until they become N.W.; but in the Caribbean Sea they are generally west, as already described.

It ought not, therefore, to excite surprise that, of the bottles thrown out, either within, or to the southward of the Gulf-stream, with a view to discover the course of the currents, the greater part should be carried to the West-India Islands, and more particularly to the *Bahamas*, from Inagua to *Eleuthera*. Those thrown out, within the verge of the Stream, go equally the same route, unless intercepted by the *Azores;* because that stream carries them finally to the S.E., and into the range of the westerly drift. I know of no instance in which a bottle thrown out *in* the Gulf-stream, or to the *southward* of it, has reached the coast of the old continent; but a great many of those, thrown out to the northward and eastward of it, have been thrown upon our Island and on the coasts of the Continent.

9.—TEMPERATURES OF THE GULF-STREAM, AND OF THE GREAT BODY OF WARM WATER FORMED BY IT, IN THE ATLANTIC OCEAN.

Few circumstances of the kind have, perhaps, occurred that have occasioned more surprise than the distance to which the warm water of the Gulf-

stream is kept up, in its progress through the Atlantic Ocean; since it may be calculated that even the strongest part of the stream cannot reach the point, at which it still preserves a temperature of 8 or 10 degrees above that of the surrounding sea, in less than seven weeks from the Sea of Mexico: and, when it reaches the Bay of Biscay, as it was once known to have done, (and therefore, no doubt, has at other times,) it was found to have a temperature of more than 5 degrees above that of the surrounding sea; although no less than 5½ months for its arrival from the Sea of Mexico can well be allowed: and after passing through a distance of more than 4000 miles, with an increase of nineteen degrees of northern parallel.

Another remarkable circumstance is the vast expanse of *warm water* which it forms in the centre of the Atlantic; and which thus becomes the *recipient* of the waters, brought and deposited by the Gulf-stream[1]: for the incessant and quick arrival of fresh supplies, keeps up the warmth of the mass[2]. The Mexican Sea, which is of much

[1] The warmth of the Gulf-stream was not known to the British public until its discovery by Sir Charles Blagden, in 1776. It had previously been discovered by Dr. Franklin, but was kept a secret through political motives. The doctor had sometime before discovered the coldness of the sea over banks; and it was in the course of these inquiries that he discovered the warm nature of the Gulf-stream.

[2] As the narrowest part of the Strait of Florida is 36 nautic miles in breadth, and the annual *mean* velocity about 73 miles per day, a surface of 2518 square miles of Gulf-water will be poured into the Atlantic every day; or about two-thirds of a

higher temperature than the ocean, may therefore be considered as a vast *cauldron*, employed in heating water, to be distributed over the central parts of the North-Atlantic; and which so affects the atmosphere as often to produce storms, that prove fatal to fleets.

It appears, from a number of observations on record, from good authorities, (and Dr. Franklin's among the rest,) that this expanse of warm water extends, *at times*, in length, from the 30th to the 75th degree of west longitude; and in breadth, at the east end, from the 33d or 34th to the 45th degree of latitude, and at the west end to between 160 and 170 miles[1]. Accordingly, there exists,

square equatorial degree. It has been shown how greatly the stream expands during its course; so that it may be easily conceived how rapidly the mass of warm water is supplied.

[1] Dr. Franklin passed through the Gulf-water in the early and middle parts of November, 1776, between the parallels of 35½° and 39°, and between the meridians of 47½° and 70° W.; and had temperatures from 75° to 81°; which were from 10° to 15° above the ocean temperature of the season. He found 77° and 78° in lat. 35½°.

2. Again, in the latter end of August and beginning of September, 1785, between latitudes 34° and 36°, and between longitudes 46½° and 70°, the temperatures were from 76° to 81°, equal to 4° to 9° above ocean temperature. He also found in lat. 34° to 33½°, from long. 31° (meridian of Corvo) to 37°, temperatures of 77° to 79°, equal to 5° or 6° above ocean temperature.

3. Captain Billings, in August, 1791, found, in lat. 37°, long. 52°, a temperature of 75°, or 4° to 5° above ocean temperature.

4. The Maidstone Frigate, at the end of June, in lat. 35½°, long. 65½°, had the temperature of 77°, or 9½° above ocean temperature.

at certain times, a body of warm water of more than 2000 miles in length, from E. to W.; and in breadth, from N. to S., at a *mean*, of more than 350 miles; a body more extensive, in point of area, than the Mediterranean Sea! This body contains, besides the Gulf-stream itself, its *counter currents*, *offsets*, or *overflowings*, and *deposits*. The stream itself, possibly, may not occupy one-half of the space.

At the same time that the above state of things serves to show how long the body of the stream, which feeds this recipient, preserves so great a part of its original temperature, although passing through all the different parallels from 25° to 45°[1]; yet the surprise is somewhat lessened by considering, that, for the most part, it runs through borders of warm water, which it has already depo-

5. The traverses across the warm water, reported by Mr. Napier, give, in lat. 35½°, long. 61°, a temperature of 70°, or 7° above ocean temperature, in the beginning of May, 1820. And also, near the end of September, 1821, in lat. 35¼°, long. 65°, a temperature of 77°, or 9½° above ocean temperature.

All these examples are in proof of the great extent of the warm water southward, in the months of May, June, August, September, and November. And,

6. The *breadth* of the warm water, when advanced only one-third of its course through the Atlantic, taken on a mean of 7 examples, is 232 miles.

It appears probable that the Gulf-water extends southward, at times, to lat. 20°; otherwise, it is difficult to account for the position of *weed* which extends between the parallels of 20° and 40°.

[1] That is, its highest northern border.

sited, and does not come into immediate contact with the increasing cold of the *water* of each succeeding northern parallel.

To this may be added that, if the temperature of the Gulf-stream, at its issue from the Sea of Mexico, had been of the same degree with that of the like parallel in the Atlantic Ocean at large, it must have been reduced to ocean temperature long before it reached the Azores. For instance, the temperature in the ocean is 78° only, at the *maximum*, in lat. 25°, but 86° in the Gulf-stream: and, being reduced in temperature from 86° to 72½° at Corvo, it would in the other case, under a like diminution of temperature, have fallen to the standard ocean temperature more than a month before its arrival at the Azores.

It has already been observed that the Gulf-water deposited beyond the borders of the stream is very unequally divided; and that by far the largest proportion of it is found on the south side: and this it is attempted to account for from the tendency of the southern part of the stream to the southward, and to the vicinity of the land to the stream, which prevents it from spreading on that side in the early part of its progress.

The breadth of the expanse of warm water increases all the way with the course of the stream; since *that* not only expands as it proceeds, but also sends forth offsets, or overflowings, from the superabundance of the fresh supplies, when the stream becomes very rapid. The traverses of the stream which have been reported, afford a full

proof of these facts; and particularly as the example which gave the *narrowest* dimensions, at a point only midway between the Strait and the Azores, was found to have increased in breadth *four-fold*, and the mean of all *seven*-fold. One must conceive the stream to be of great depth; for no doubt it has worn the narrow strait to a vast depth, and would, of course, occupy the whole space.

It is indeed probable that its depth may be far beyond the extent of ordinary belief. No person has yet searched the depth of it; but, in another case, the *Lagullas Current*, its *body* is evidently turned aside by the edge of a bank, over which there is more than 100 fathoms' depth of water! And if this be admitted of the Gulf-stream, there is, no doubt, ample scope for spreading.

It is proper to remark, that the temperature along the track of Dr. Franklin's vessel, in 1785, and which appears to be nearly the southern boundary of the tract of warm water (that is, the parallels of 34° and 35°), corresponded, very nearly the whole way, with the temperatures *opposite to them in the Gulf-stream;* at the like season, that is in August, Captain Billings's observations prove the same. And, generally speaking, the intermediate temperatures, *across* the recipient, agree also with those in the stream; allowance being made, in all cases, for the difference of parallel, when necessary, in order to make the comparison between

the temperatures of the *Gulf-water* and that of the *ocean*, in each parallel.

This agreement of temperature can hardly be accounted for on any other ground than that of the copious overflowings of the stream, as it proceeds eastward. The temperature of the stream, of course, diminishes as it advances; therefore, any portion of its waters, returning in the form of a counter current, would of necessity be *cooler*, in any given place, than the opposite part of the main stream. But, on the contrary, it is found that the water of the recipient becomes *warmer* as we advance westward; that is, agreeing nearly with that part of the stream opposite. Nothing, therefore, can well account for this, but an almost perpetual overflowing of the stream as it proceeds. As, for instance,

The temperature was found to be 74° in August, at the place where the stream turns towards the S.E., in long. 40°; and was 80°, in the like season, in long. 56°, lat. 34° to 35°; that is, at a point about midway between the first-mentioned meridian and the place where the Gulf-stream leaves the coast of America. At about 5 degrees to the northward of the place of the 80°, the temperature was 77°; which exactly corresponds with the other three degrees, being the required deduction for the difference of parallels, in order to reduce it to ocean temperature. Now, as the temperature was 74° before the stream turned to the southward, how was it possible that, after having ran 900 miles

to the westward, it should have acquired a higher temperature by 6 degrees?

On the whole, one must naturally conclude, that the principal cause of the greater accumulation of warm water on the *south* of the stream, (and, indeed, almost exclusively there,) was the bending of the stream, to the S. and S.W. at the Azores, as before described. For, by this change, not only a great proportion of its water is turned to the south and S.W., but, by its new line of direction, it becomes a kind of *bar* to the passage of the off-sets; whose waters must therefore *accumulate*, and seek an escape towards some other quarter. That quarter, of necessity, must be the S. or S.W., and towards which the head of the impeded waters will accordingly turn; and, successively, all the other parts which follow, as the impulsion is communicated westward.

This operation (if admitted) would account for the great extent of the warm water to the southward of the stream itself, as also for its high temperature, as being *drawn immediately* from the body of the stream. It would also account for the *shape* of the expanse of warm water; since the accumulation would, of course, increase as the stream advanced, and add continually to the mass by its spreading and overflowing. And, lastly, it may be supposed to furnish a great proportion of the materials of the counter current, whose existence has been so satisfactorily ascertained, and whose commencement may surely be referred to the S.W. *bend*, above described, as its incipient cause, and

which is afterwards increased by a part of the overflowings.

When the bulk and rapidity of the stream, at its issue from the Strait of Florida, are considered, there is surely nothing improbable in the supposition of its forming so vast a body of warm water. A *sea current* is not like the *stream of a river, which passes on* in its way to the sea, but rather like one that should finally spread its waters over a level country, in the form of a lake; and which should, moreover, in its way through that level country, often overflow its banks. The quick and incessant arrival of fresh supplies of warm water, and the length of time required for it to cool, of which there is a specimen in the very slow manner in which the warmth of the Gulf-stream diminishes, might alone satisfy the mind, in respect of the possibility of so great an expanse of warm water being collected. Even if fresh supplies were discontinued, it must require a considerable length of time to cool to the standard of *ocean temperature.*

Every other current must, of course, produce the same effects, in a degree, in displacing a body of ocean water equal to that which it brings; but differing little, or perhaps nothing, in point of temperature, the *stagnum* does not manifest itself, like that of the Gulf-stream.

But nothing less than a great number of observations of every kind, and those made through many seasons, in order to embrace all the varieties of cases, can enable the most diligent inquirer to make himself master of the whole subject; *and this*

can be the work of Government only; for individual inquiry can produce little more than unconnected facts.

I now come to the DETAIL *of the* TEMPERATURES *of the* STREAM *itself*, through the whole extent of its progress, as well as of the *extension* of the warm water, (and doubtless of the stream itself, although its motion could not be detected,) to the coast of Europe.

Allowances, no doubt, are required to be made for the difference of thermometers, and also for the different modes in which the observations were made by different persons; and, in a very few instances, at different hours of the day. But even taking the observations as they arise, one is really surprised at the general agreement that is found amongst them, when the proper allowances are made for difference of parallels and seasons.

But the principal part of the examples of the temperature, through the Gulf-stream generally, that have come to the Author's hand, were made during the summer seasons of each year: whence it happens that the *maximum* temperature alone could be adopted as a standard; as being the only one that could be verified throughout the series. For, as the Strait of Florida is little frequented during the winter months, because of the northerly winds, there have been very few observations of the rate of the stream collected, or of the temperature of the sea at that season.

There will be found, hereafter, two distinct Tables

of the Temperatures, through the whole extent of the stream, from the Mexican Sea to the Azores. The first is by Captain Livingston alone, and so late as 1818; the other from various authorities, and of different dates. It was judged proper to give the former matter in a separate table, as being the result of the *same* observer, with the *same* instruments, and with a regular series of corrected longitudes. It will appear that the two are not inconsistent with each other; but, of course, the former claims the preference as a system, for the reasons above mentioned. [*The Tables are given in the Appendix.*]

By these Tables, it will appear, that the diminution of the temperature is pretty regular during the progress of this wonderful stream; and correspondent with the abatement of the velocity of the currents, through a course of more than 3000 miles from its outlet.

The numerous transits across the Gulf-stream, already examined, in which the temperatures have been so carefully noted, have furnished much matter for the illustration of this subject. These having been made during seven different months of the year, afford a large field for comparison: and although confined to one quarter of the stream alone, yet the principle may easily be transferred to the remaining parts.

The transit by Mr. Napier, in February, 1820, [A.A. *in the Chart*] furnishes the only example of the *minimum* temperature, (or what may be deemed very nearly such) of the Gulf-water, in that place; which is at about the distance of 1500 miles, from the outlet

of the Stream from the Sea of Mexico; or somewhat more than half the length of its ordinary course through the Atlantic. By the help of *this minimum* example, and of *several* examples of the *maximum* temperature about the same place[1], we are enabled to make a comparison between the summer and winter temperatures of the Gulf-water. The one was 81°, the other 67°; whence arises a difference of 14°, which differs but little from that between the highest and lowest *ocean temperature* of that parallel (39°), which is 13°; the one being 69½°, the other 56½°. And the Gulf-water of the summer and winter examples (81° and 67°) were respectively 11½° and 10½° above the ocean temperature of the two seasons.

The temperature of the Gulf of Mexico is known to the Author only in the single instance communicated by Captain Livingston. All *close* seas are known to be (*cæt. par.*) warmer that *oceans*. The sea in question is 86° at *maximum*, at the outlet of the Gulf-stream, and this temperature continues to 24½° of latitude: but the Atlantic, in latitude 25°, is no more than 78°, whence arises, of course, a difference of about eight degrees[2].

[1] The near or rather exact agreement of the following gentlemen, is remarkable:—

Captain Pell, end of July,	lat. 39°,	long. 63¼°,	temp. 81°.
Colonel Williams, August,	— 39°	— 64°	— 81°.
Captain Livingston, Sept.,	— 38¼°	— 63¾°	— 81°.

[2] The Caribbean Sea is also warmer than the Atlantic; and grows warmer as we go towards the Gulf of Mexico; although

It appears, also, by Captain Livingston's observations, that the Gulf-stream loses three degrees, (and no more,) in its way to Cape Hatteras; the first 300 leagues of its course; where it is 83°. And, in the course of 200 leagues farther, that is, to the place of the traverse of Feb. 22, 1820, (long. 63½°,) it loses 2° more, or falls to 81° (*maximum*). Thus the abatement of warmth, in summer, is five degrees; but in winter, it must be very much greater, from the twofold cause of being *longer* exposed to a *colder* sea and to a colder atmosphere: for the loss of heat must depend, in a great measure, on this circumstance.

This is exemplified in the case of Dr. Franklin's voyage from the Delaware to the Bay of Biscay, in November, 1776. He then found the Gulf-

the parallel is raised several degrees. The observations extend only from Barbadoes to Jamaica.

It was observed, that, in the parallel of Barbadoes, and between the meridians of 54° and 57°, in the Atlantic, the temperature was from 82° to 83½°, in the beginning of November; which is higher, 2 to 2½ degrees, than on either side. At the same time, a considerable current from the S.E. ran through the space which contained the warmer water; proving that it was from the Equatorial regions. But the stream in question, by its direction, would not enter the Caribbean Sea, but pass wide of it to the northward.

Near Jamaica, in lat. 17½°, the temperature was 82° in the middle of November. This appears to be even higher than the *maximum* temperature of this parallel in the Atlantic and other oceans, at large; but the quarter of the Atlantic adjacent to the northern coast of South America, appears to be warmer than the like parallels elsewhere; which may be owing to the general motion of its waters from the warmer regions on the south.

water 77° in lat. 38° to 39°, at 1300 miles from the American coast; two degrees higher in the middle of *November* than Captain Billings found it in *August*; that is 75°: and, indeed, the water, the whole way, after he entered the Gulf-stream, was of a *much higher* temperature than usual at that season: that is, 3 to 5 degrees. This must be accounted for, chiefly, on the supposition of a stronger current than usual; and accordingly, *the Gulf-water reached the coast of France in that season.*

I calculate that the stream may probably employ, in summer, twelve days in its passage from the Sea of Mexico to Cape Hatteras (924 miles.) The small decrease in the temperature is the more remarkable, as, during the interval, it passes through eleven degrees of latitude (24° to 35°), and through ocean water diminishing 6° of temperature.

Thence, to the traverse of February 22, 1820, (615 miles), it may probably take also 12 days. In this interval the temperature decreased two degrees only, and the latitude four degrees; so that, in passing through 15 degrees of higher latitude, in 23 days, the water lost only 5° of its warmth in summer: that is, from 86° to 81°.

Thence, to lat. $42\frac{1}{2}°$, long. $43\frac{1}{3}°$, a distance of 950 miles, it may be supposed to employ 24 days; and loses $5\frac{1}{2}°$ more of temperature, or from 81° to $75\frac{1}{2}°$. Here the increase of parallel is about four degrees only, but the time nearly double to that of the last interval; the distance being about one half greater, and the rate, of course, diminishing.

And, finally, to the neighbourhood of *Corvo*, 570 miles, it loses only three degrees, or falls from 75½° to 72½°, although it may probably employ 30 days. Here, it must be observed, that the course of the stream, through this interval of space, is to the *southward* of east, *diminishing* the parallel 2½° degrees: whereas all the others have been to the *northward* of east, *increasing* the parallel, and, consequently, the degree of cold. But this does not satisfactorily account for the small diminution of temperature in 28 or 30 days. It shows, however, how slowly the water cools.

It happens fortunately in this instance, that the result does not depend on single examples or authorities. There are no less than *four* observations of Captain Beaufort and Captain Livingston, in and about long. 45°, and between the latitudes of 40° and 43°; and at Corvo and Flores, *two* others[1]: not to mention the *regular diminution* of temperature from longitude 45° to Corvo.

[1] Captain Beaufort, in August, lat. 43½°, long. 45°—76°.

Ditto, in nearly the same place, 76½°.

Captain Livingston, latter end of September, lat. 40°, long. 43½°—75°.

Ditto, lat. 39½°, long. 47½°—77°,

At Corvo and Flores.—Captain Beaufort, north side of Corvo, August, 72°.

Captain Livingston, beginning of October, south side of Flores, 73°, 74°.

It is shown by other examples, that the water was warmer on the south of Flores than north of Corvo; the Gulf-water passing along the S.W. side of the Azores.

Taking the result, as it appears by the authorities, the Stream, in running through about 3060 miles, and altering the parallel 18 or 19 degrees, (*i. e.* from 23½° to 42° or 43°,) diminishes its temperature about 13½ degrees, (86° to 72½°,) and may be supposed to employ from 76 to 78 days[1] on its passage.

The *data* on which the time is calculated, is the *mean* velocity of the Stream in summer, between the different points. Thus, between the Sea of Mexico and Cape Hatteras, it is taken at about 3¼ miles per hour, or 77 to 78 miles per day, the rate varying from 4, and occasionally 5, to 2½ and 2 miles *per* hour. Between Hatteras and a point in the traverse of Feb. 22, in lat. about 39° 5′, is taken

[1] If the calculation be limited to the first three intervals, as the fourth is uncertain, we have the following proportions:—

Latitude.	Longitude.	Diff. Lat.	Distance.	Number of Days.	Temperature.	Diminution.	Above Ocean Temp.
From 23½° to 34½°	Hatteras. 75°	N. 11°	924	12	From 86° to 83°	3°	12°
38⅔°	⊙63¾°	4°	615	12	81°	2°	13°
42½°	43⅓°	4°	950	24	75½°	5½°	8½°
		19°	2489	48		13½°	
40°	31°	S. 2½°	571	28 to 30	72½°	3°	6½°
			3060	77			

From Hatteras to lat. 37⅓°, long. 71½°, 241 miles. To ⊙ 374 miles. Total 615.

at $2\frac{1}{8}$ per hour, or 51 to 52 miles *per* day. Between that point, and another in lat. 43° 18′, long. 42° 30′, (being considered as the middle point of the Stream, between Captain Beaufort's observations on the N., and Captain Livingston's on the S.), $1\frac{2}{3}$ *per* hour, or 40 miles *per* day. And finally, between this latter point and Corvo, 19 or 20 miles *per* day, the rates varying gradually from 31 to 10 miles[1].

The traverses above recorded, point out, most clearly, the regular diminution of the temperatures, from the centre of the warm water to the extreme boundaries on both sides. It also appears, generally speaking, that the highest temperature is rather to the north of the centre; and as far as the observations go, the strongest part of the Stream is there also.

It appears also, in more than one instance, when the volume of warm water was widely extended to the southward, that the temperature, after

[1] It is to be understood, that these several rates represent the mean velocities of the Gulf-stream, through the intervals between the several points above indicated; but not the absolute velocity *at* the points themselves. As, for instance, the *mean* velocity at the *Narrows* of the Florida Strait is taken at 86 to 88 miles per day; and that at Cape Hatteras at 68; and hence a *mean* of 77° to 78° through the interval, is taken. This is a rule adopted through necessity; as a sufficient number of examples do not occur within the intermediate space, as was also the case in the last two intervals.

But in the interval between Hatteras and the traverse of Feb. 1820, the rate is made up from the intermediate examples, as furnishing a more satisfactory result than might be obtained by taking the *mean* between the two extremes.

having *abated*, again *increased*; and this I have elsewhere supposed to be the effect of counter current.

It has been also suggested, that the vicinity of the land to the westward, after the escape of the Gulf water from the Strait of Florida, by preventing the Stream from spreading on that side, may, in the first instance, be the cause of the greater expansion of the warm water towards the side of the ocean. This might also account, in part, for the stronger current and warmer water being towards the northern side of the stream.

Mem.—It appears highly probable that a portion of the Gulf-water may extend itself even to lat. 20°, although no current may be perceptible; otherwise it is difficult to account for the almost fixed position of the mass of Gulf-weed generally existing from 40° to 20°.

10.—EXTENSION OF THE GULF WATER TO THE COAST OF EUROPE.

It has been mentioned, in the course of the preceding observations, that the Gulf water, in one instance, was found to extend to the coasts of Europe. This took place in Nov. 1776, and was observed by Dr. Franklin himself, in his voyage from Philadelphia to France, during which *he was never out of the warm water of the Gulf-stream;* and which, according to the examples compared with others of corresponding seasons, appeared to be of a much higher temperature throughout; and

that high temperature extending much farther eastward than usual.

The Doctor's journal of the temperatures, affords some curious facts respecting it. One circumstance is the very slow degree in which the Gulf-water cools, even at the height of the parallel of 45°, in the month of November. And this example is the more decisive, as it is taken on a very long line of distance, (about 1150 miles,) confined very nearly to that parallel, and with no longer interval of time, between the first and the last of the observations, than is usually employed in navigating it.

In effect, at 85 leagues to the W.N.W. of Cape Finisterre, the temperature, at the latter end of November, was only four degrees below the *maximum* of summer heat in the ocean in that place; although the *maximum* and *minimum* heat, in that parallel, differ 14 degrees of Fahrenheit; and as this can be accounted for only from the presence of *Gulf-water*, the Stream must have gone 1100 or 1200 miles farther than at ordinary times; or, on the whole, upwards of 4000 miles. And moreover, the direction in which it was thus prolonged, to the coasts of Europe, was the same which it had previously taken through the western half of the Atlantic[1].

[1] Here it should be observed, that, admitting that the Gulf-stream continued its course on the same line of direction on the globe, that is, on a portion of a great circle, on which it is known to run, through 500 leagues of the western part of the Atlantic, its course *by the compass* would naturally become more and more

The authority for this fact is very *clear* and decisive ; for the decrease of temperature was regular the whole way, according to the order of time in which the water may be supposed to have arrived, and to have been acted on in passing through a longer or shorter space of colder water. Moreover, the known accuracy of the Reporter still adds to the weight of the authority.

It fortunately happens, also, that besides this direct information, we are enabled to compare the observations in this voyage, made in November, 1776, with others, taken one month of the year later, December, 1789 ; each of these voyages, respectively, employed the whole month ; and both of them may be compared with observations made by Captain Beaufort, in nearly the opposite season, *i. e.* August, 1809. By these it will appear, how nearly the *winter* temperature of 1776, and that of the *summer* of 1809, agreed in that place, which lies within the ordinary course of the Gulf-stream ; and, on the other hand, how widely the two winter temperatures, of 1776 and 1789, of one month's difference of time only, differ from each other, and that at a season when the sea is clear of ice.

The particulars will be found in the accompanying note [1], and the comparisons, in a general view, are as follow :—

eastwardly ; owing to the approximation of the meridians on the Globe, to each other.

[1] The following particulars are extracted from two Journals, from the *Chesapeake* and *Delaware* towards Europe : that is,

Where the routes first crossed each other, that of November, 1776, had, numerically, eight degrees of temperature higher than that of December, 1789 : and, in the others, respectively, 11, 9, 12, and 6, degrees. But here it is to be observed that, the difference of temperature, during the interval of the month that elapsed between the observations, requires a deduction of about two degrees, at least, from the November observations ; as, from experience, the sea may be expected to cool so much ; whence the differences, under a fair comparison, must be reckoned, respectively, at somewhat less than 6, 9, 7, 10, and 4, degrees.

Since then the temperatures in *November*, 1776, fell so little short of those which are usually found in *August*, one cannot but conclude that the current had a greater degree of velocity also ; and had brought on the warm water quicker than usual.

one kept by Dr. Franklin, in November, 1776 ; the other in the Mercury, December, 1789.

These tracks either *cross*, or run very close to each other, in about lat. 42½°, long. 39°, (A) : and a third track, Captain Beaufort's, in August, 1809, *crosses both*, at nearly the same place.

The two former again cross each other, or pass close, in lat. 37°, long. 62°, (B): in lat. 40°, long. 47°, (C): in about 44½° lat., 34° long. (D): and in lat. 41½°, long, 42½°. (E)

(A) Where the three cross, the August temperature was 74°

That of { the middle of November, 71, 72°
the middle of December, 59°

(B)	That of	Nov.	76°	(D)	That of	Nov.	63°
		Dec.	68°			Dec.	57°
(C)	That of	Nov.	71°	(E)	That of	Nov.	68, 69°
		Dec.	60°			Dec.	59, 60°

Certain it is, that many ships have sailed over and across that part of Dr. Franklin's track, between the Azores and Europe, and have uniformly found the sea of no higher than *ocean* temperature.

It may be supposed, from the known general velocity of the Gulf-stream, that during the summer months, when the greatest velocity, as well as the highest temperature, takes place, that the Gulf-water cannot reach the Azores in less than about 11 weeks, from the outlet of the Sea of Mexico: but, from the Azores to the coast of Europe, for which we have no *data*, the time can be guessed only. Nor are we in possession of any other particulars, relative to the Gulf-stream, in 1776, that might lead to any conclusion concerning its velocity or temperature at the outlet.

The distance from the Island of Corvo to the head of the Bay of Biscay, is about 1150 miles. It was found in three different years, by as many different observers, and by all, either in the month of August, or early in September, that the velocity of the Stream, between the meridians of 41° and 45° W., was from 30 to 33 miles during the 24 hours. It was stated above, that about the longitude of 40°, the Stream begins to turn towards the south of east, and gradually round to S.E. and south, to Corvo and Flores. Also, that its velocity was reduced to 18 miles *per* day, in long. 38°, or nearly 300 miles short, or to the westward, of Corvo.

Now as observations, made in different years, have proved, most satisfactorily, that the Gulf-

stream turns to the S.E., and then south to Corvo, one may conclude that this is its usual place and mode of termination; and more particularly as *cold water*, or ocean temperature has, in every instance, save the one in question, been found to the N.E. and E.N.E. of the place where the Stream thus turns to the S.E., that is, in the line of direction of Dr. Franklin's route towards Europe; and, indeed, it may be said, that the sea has been found of ocean temperature in *every direction*, between the Azores and the coasts of Europe and North-Africa[1]. Moreover, the sea has a general tendency to the southward, from our parallels, between the Azores and the coast of Europe; and, in approaching the latter, the water is found *still cooler* than ocean temperature, as coming from a parallel which has an admixture of Arctic water with it.

Is it not, then, reasonable to conclude, that, in the instance noted by Dr. Franklin, the *body* of the Gulf-stream had, at that time, a more than usual degree of velocity; and that, instead of turning, as at other times, to the southward, continued (or at least, a great proportion of it,) on the course it had already held through the Atlantic?

A greater degree of velocity than usual was doubtless required; otherwise, as it is found in ordinary years to have diminished its rate, in the course of 1500 miles, from 85 to 51 miles per day,

[1] The reader is reminded, that Captain Livingston once found warm water extending all along the S.W. side of the Azores.

and in a course of 950 more to 31 ; in what interval of time could it be supposed to pass through another space of 1750 miles, with a constant diminution of velocity, from 31 ? But it *had* passed through that interval[1], and still preserved such a portion of its *warmth*[2], as was equal to seven degrees above ocean temperature, (*i. e.* 62° at the latter end of November, in lat. 45°, and upwards,) within 85 leagues of Cape Finisterre. Probably, also, the water may have originally attained a higher degree of warmth than usual.

One may also conclude that the Gulf-water had recently arrived at that point ; and that its warmth had been partly kept up by the operation of the summer heat, in the course of its passage. It has been stated that about eleven weeks are probably required for the water to reach the Azores ; and, perhaps, not less than three months more to reach the interior of the Bay of Biscay, at such a reduced rate of velocity as must necessarily have taken place ; even admitting that the Stream, in that year, had a more than ordinary velocity, as may justly be concluded ; and, accordingly, 5½ months

[1] The position in which the rate of 31 miles was found, (and which was short of the place where the stream usually turns to the south-eastward), was 1750 miles from the Bay of Biscay, in a *direct line*, and not through Corvo. It may be conceived, that in the season when the Stream reached the coast of Europe, it ran with a more than usual velocity, and did not turn at all to the S.E., as when it terminates near the Azores.

[2] The currents, unfortunately, are not recorded ; probably were not ascertained ; as it was previous to the date of lunar observations and time-keepers.

may be reckoned from the Sea of Mexico to the Bay of Biscay. And hence it may be conceived that the warm water, which was found in that Bay, at the end of November, might have issued from the Gulf of Mexico in the month of June, and have passed the Azores in August.

Dr. Franklin, after crossing the track made by Captain Beaufort, in long. 38°, lat. 42½°, continued his course to the eastward, crossing the meridian of Corvo, in about the parallel of 45°, and at one degree to the eastward of it, (*i. e.* in 30°,)[1] found a temperature of 65°, and saw Gulf-weed. The *maximum* temperature of 45° is 66°, and *minimum* 52°, in January; therefore, the actual ocean temperature at that time, being about 55½°, the water was no less than 9½° above ocean temperature.

Advancing nearly on the same course, six more degrees of longitude towards the Bay of Biscay, (*i. e.* to long. 24°,) the temperature was reduced one degree, or to 64°; or still 8½° above ocean temperature; and in this place, in August, 1809, Captain Beaufort found only 66°: and here it may be observed, that Dr. Franklin's *then* station was on a continuation of the line of direction of the Gulf-stream, from the Chesapeake to the place where it has been described to bend from its east-northerly course in longitude 40°; from whence may be concluded, that the stream, or a large por-

[1] A position, equally advanced with Corvo, from the Strait of Florida.

tion of it, instead of turning to the S.E., as at ordinary times, had continued its former course; having, probably, a greater velocity than usual.

The temperature decreased very slowly: in long. $20\frac{1}{2}°$, it fell to 62°, and continued, to long. 15°, still seven degrees above ocean temperature: and *in this place*, in August, 1785, the Doctor afterwards found 66°; or only 4 degrees above what he experienced at the end of November, 1776! And, finally, he found, through $12\frac{1}{2}$ degrees of longitude, or to long. $2\frac{1}{2}°$ W., and near the coast of France, 61°, and 60°; which latter was even $5\frac{1}{2}$ degrees above ocean temperature [1].

It appears most probable then, that the Gulf-water had but recently arrived, and had not had time to cool to ocean temperature; for, any degree of temperature that it can well be supposed to have had, on its arrival at that point during summer, may, at the latter end of November, have cooled down to ocean temperature.

[1] The decrease of temperature was nearly as follows:—

Time, 1776.	Latitude.	Longitude.	Temperature.	Above Ocean Temperature.
In the middle of November.	° $42\frac{3}{4}$	° 38	° 71	° 14
	$43\frac{1}{4}$	35	68	11
On the last ten days of November.	45	30	65	$9\frac{1}{2}$
	$45\frac{3}{4}$	24	64	$8\frac{1}{2}$
	$45\frac{1}{2}$	$20\frac{1}{2}$	62	7
	$45\frac{1}{2}$	18	62	7
	$45\frac{1}{4}$	15	62	7
	45	$10\frac{1}{2}$	61	6
	$45\frac{3}{4}$	$6\frac{1}{2}$	60	$5\frac{1}{2}$
	$45\frac{1}{4}$	$2\frac{1}{2}$	60	$5\frac{1}{2}$

It may well be supposed that, at times, under increased degrees of velocity, the Gulf-stream may advance more or less, beyond its accustomed place of termination near the Azores, towards the coasts of Europe, although it has been detected in this single instance only. Had it happened frequently, it could hardly have escaped observation; considering the number of experiments made by ships, in these times, in their courses from our parallels, southward [1]. On the contrary, nothing higher than ocean temperature has been observed between the Azores and the coasts of the old Continents, since Dr. Franklin's voyage in 1776, until Captain Sabine found the like results in 1821.

Baron Humboldt, who had doubtless seen Dr. Franklin's journals, calls this the *northern branch* of the Gulf-stream; perhaps considering it to be permanent; but he also speaks of the *southern course* of the body of the stream, near the Azores.

In some charts are found "*Indications of the Gulf-stream,*" in about lat. 47°, long. 39°, 1745: and again, in lat. 45½°, long. 34°, in 1771. The nature of the "*Indications,*" is not mentioned. The warmth of the Gulf-water had not been noticed in 1771; and, therefore, perhaps, Gulf-weed, seen in those situations, might have suggested the idea. But it is well known that the Gulf-weed is thrown up, on the coasts of Europe, and North-Africa, by the reigning winds of those regions [1].

[1] Captain Scoresby, in his interesting and instructive work on

REMARKS ON THE EASTERN EXTENSION OF THE GULF-STREAM, DEDUCED FROM THE VOYAGE OF CAPTAIN EDWARD SABINE, 1822.

Since the preceding discussion was written, the Gulf-water has again been found near the coast of Europe, by Captain Sabine, in his way southward, on his scientific voyage, in January, 1822.

Here follows his TABLE of TEMPERATURES.

	Date.	Latitude.	Longitude.	Temp.	Surface Water.		
	1822.			Air.	Observed.	Usual.	Excess or Defect
Plymouth to Madeira.	Jan. 5	47° 30′ N.	7° 30′ W.	47°	49°	50°	−1°
	6	44 20	9 30	52·5	55·7	52·5	+ 3·2
	7	41 22	11 37	54	58·2	54	+ 4·2
	8	38 54	13 20	54·2	61·7	55·7	+ 6
	9	*No Observation.*		56	63	58	+ 5
	10	33 40	15 20	60·7	64	60	+ 4
Madeira to the Cape Verde Islands.	19	26 0	17 50	66	65·5	67	− 1·5°
	20	24 30	18 50	68	67	68·4	− 1·4
	21	23 6	20 0	69	69	69·5	− 0·5
	22	21 2	21 27	69·5	69·5	71·2	− 1·7
	23	19 20	23 0	70·6	70·2	71·6	− 1·4

Hence it appears that, in latitude 47½°, in the Bay of Biscay, the temperature was 49°, which is

the Arctic Regions, (vol. i. p. 209,) expresses an opinion, that the northern branch of the Gulf-stream, after reaching the coasts of *Britain*, pursues its way to that of *Norway*. But he does not produce any facts, to show on what authority he grounds an opinion contrary to those which commonly prevail: and, it may be said, to facts, as far as they are known.

one degree below the natural temperature of the season; but that, on the following day, in latitude $44\frac{1}{3}^{\circ}$, at about ninety miles to the northward of Cape Finisterre, the temperature was $55 \cdot 7^{\circ}$, and, consequently, had increased $6\frac{3}{4}^{\circ}$, although the ocean temperature should have increased $2\frac{1}{2}^{\circ}$ nearly; so that the present temperature was $3\frac{1}{4}^{\circ}$ above ocean temperature. It is not known when it began to increase, probably imperceptibly. On the succeeding day, 7th January, in lat. $41\frac{1}{2}^{\circ}$, it had still farther increased beyond ocean temperature; at fifty-seven leagues west of Oporto, this latter being 54°, and the present temperature of that parallel $58 \cdot 2^{\circ}$, and, consequently, $4\frac{1}{4}^{\circ}$ above ocean temperature. Next day, the 8th, in about lat. 39°, and sixty-three leagues to the westward of Lisbon, they found a still further increase of temperature, it being $61 \cdot 7^{\circ}$ or $6\frac{1}{2}^{\circ}$ above ocean temperature. This was the highest, or $6\frac{1}{2}^{\circ}$ in respect of ocean temperature, which they experienced.

On the following two days, the 9th and 10th, the last of which brought them to lat. $33\frac{2}{3}^{\circ}$, and at twenty-seven leagues to the N.E. of Madeira, they had reduced the temperature to 5° and 4° above ocean temperature.

It will appear that, after leaving the island of Madeira, in latitude 32°, on the 19th to the 23d of January, when near the Cape Verde Islands, they experienced, universally, a temperature *colder* than ocean temperature, (which is usually the case, and in a much greater proportion, all the way from our

parallels,) by 1·4° to 1·7° on each day, save one, and then only half a degree [1]. In effect, the actual temperature of the sea increased only 1½° in going from 33⅔° to 26°, equal to 7⅔ degrees of latitude, although the difference of ocean temperature between these parallels is full seven degrees; that is, 60° and 67°. When this circumstance is compared with what happened between the 47½ degree of latitude and 39°, when a difference of no less than 12¾° took place in the rise of the actual temperature, in the course of 8½° degrees, as well as the coldness of the sea afterwards, one cannot but suppose it to be occasioned by the presence of Gulf-water.

One is naturally led to suppose that the temperature of lat. 39°, being the highest in respect of ocean temperature, and its gradually falling on each side of it to the extent of five degrees or more, north and south, that the centre of the Gulf-water was in 39° in that quarter, as we have said elsewhere, and given a supposed reason.

But this vast breadth of the warmer water, no less than 10⅔ degrees, or 640 miles, seems only to be accounted for on the ground of its being the *recipient* or *stagnum* of the water of the Gulf-stream when it reaches so far, distributing itself along the coasts

[1] *Remark.*—As the water there was *below* ocean temperature, it must be referred to a southerly current, which would, of course, be cooler than ocean temperature, as coming from our parallels, [*See Tables of Currents*]: and, therefore, it may be with justice presumed, that the admixture of this southerly current with the waters of the Gulf-stream had lowered the latter, although it still continued at a much higher temperature than that of the ocean.

of Europe, in this case, as along the Azores and their neighbourhood, in ordinary cases, and probably more to the southward, because the North-African current has a tendency that way.

As Dr. Franklin's experiments were confined to a single line *along* the Gulf-stream, neither the middle of it was thence known, nor the position of its borders, in any part; so Captain Sabine's line of experiments was *across* the stream, from N.N.E. to S.S.W. But, from what is known, it seems improbable that Dr. Franklin's track lay through or near the centre of the warm water; but rather towards its northern extremity. For the highest *known* point, northward, of the body of the Gulf-stream, in the mid-Atlantic, is between 44 and 45 degrees of latitude; so that it seems most probable that the centre of the stream should fall about the parallel of 39° or 40°, on the coast of Europe. This is supposing that, when it reaches Europe, it continues from the mid-Atlantic on the same course as it came to it from opposite the Chesapeake, that is, on a section of a *great circle* on the globe for the bearing; which varies, of course, with each meridian it passes, and must be laid out of the question.

But the centre might, indeed, have been *more to the south*, as we have no exact knowledge of the place of the southern border of the Gulf-stream in the mid-Atlantic, like that on the north, as given by Captain Beaufort; consequently, it may be supposed that Dr. Franklin was near the northern border of the stream. The only computation in

regard of temperature (present or actual, in contradistinction to ocean temperature) that can be made between Dr. Franklin's and Captain Sabine's, is at the station of the former, in lat. 45° N. and long. $10\frac{1}{2}$° W., and at that of the latter, in lat. $44\frac{1}{2}$°, long. $9\frac{1}{2}$°. Dr. Franklin's experiment was 61° near the end of November; Captain Sabine's $55\frac{3}{4}$°, beginning of January. The former being 6° above ocean temperature, the latter $3\frac{1}{4}$°; but this is merely numerical; for Captain Sabine's had been subject to six weeks' cold of the month of December, and a part of the preceding and succeeding months, equal, perhaps, to 3° or more; and then Dr. Franklin's, so reduced, must be taken, on comparison, at 3°, or less, above ocean temperature, and, consequently, agreeing closely with Captain Sabine.

In two of Mr. Napier's traverses across the Gulf-stream, in the Atlantic, we have an illustration of the above facts. In February, 1820[1], he found the warmer water 67°, which was one-third from the northern border, and two-thirds, of course, from the southern; and from that point the temperature diminished on the north to 63° at half way, and 62° near the border; and on the south, in like manner, to about 63° midway, and then 61°, and then 62° to the border; or, in other words, above ocean temperature $9\frac{1}{2}$° at the highest, with a diminution to 7°, 6°, and 5°, northward; $7\frac{1}{2}$°,

[1] Traverse (A A.) in Chart V.

8°, 6°, 5°, and 3°, southward. Breadth of the stream 140 miles.

And again, the same gentleman, in September, 1821, [*traverse* H. H. Chart V.], when the Gulf-stream was half as wide again, 223 miles, as in the former case, the body of the stream was from $80\frac{1}{2}$ to 78°, but diminished as in the other case, towards the borders ; so that midway, between the centre and the border northward, it is from $80\frac{1}{2}$ to 79, 78, 77°, and afterwards 74° and 71°.

These examples are very much in proof of the identity of the waters examined by Captain Sabine, with that of the Gulf-stream ; for besides the regular degree of warmth on each side of the parallel of 39°, it has appeared that he found *cold* water, indeed somewhat colder than ocean-temperature, beyond it, both to the north and south.

But the difficulty of judging where the centre of the Gulf-water was, at the time of Dr. Franklin's voyage, still remains. By what has been said above, it cannot well have been in a much higher parallel than 39° or 40°, and Franklin's observation, consequently, near the border of it; yet the water, reduced to a comparison in time with Captain Sabine's observation, was at least 3 or 4 degrees warmer.

11.—The NORTH-AFRICAN and GUINEA CURRENT.

The North-African and Guinea Current has already been defined in the General View of Cur-

rents, pages 32 to 40. By this Current, therefore, is meant that motion of the sea, proceeding from our parallels, which often occasions unwary navigators to be thrown ashore, even in fair weather, on the coast of the *Sahara*, or Great Desert of Africa.

The subject of this Stream, or rather Streams, is intricate, as it has various ramifications, which take different lines of direction, though all of them, bating those which point towards the entrance of the Strait of Gibraltar, to supply its current, point in some degree southward.

If we take up the consideration of the North-African Current at a point about sixty leagues to the N.W. of Cape St. Vincent, and in the parallel of 39° N. it will be found that, from such point to Cape Cantin, (in lat. 32° 35′,) the currents, from every quarter, point towards the Strait's mouth, as to the *pipe of a funnel*, of which the *reservoir* is the semi-circular space between the Capes of St. Vincent and Cantin. And this is so palpably the case, that several navigators, who have made use of chronometers, have spoken of currents pointing that way. But it does not seem to have been suspected that this influence extends very far into the Atlantic, in different directions; and especially during the *summer*, when the evaporation of the Mediterranean Sea, (which these Currents are supposed to replace,) must be greatly increased[1]. It is ascertained, by

[1] It is this circumstance which renders the currents in-shore so fatal.

the Journal of the *Solide*, in the summer of 1792, that, from the Western-Islands to the above *reservoir*, there was a regular flow of half a mile per hour, the whole way; and in a direction pointing exactly towards it; that is, about E.S.E. ¼ S.; and beyond Cape St. Vincent, the rate increased to three quarters of a mile per hour.

Between the Strait's Mouth and Cape Bojador, in latitude 26° 7′, that is, an interval of ten degrees of latitude, along shore, the motion of the sea, to the distance of more than 100 leagues from the shore, *points obliquely towards it.* Much the same state of things prevails as far as Cape *Blanco*, five degrees farther to the south; only that, within *this* interval, the *inset* extends no farther from the shore than 50 or 60 leagues, instead of 100, as in the former interval. And beyond this distance, the current runs in the direction of the trade-wind; *i. e.* to the S.W.

The state of things then is, that through the space of about 350 leagues, the current sets obliquely towards the shore; in one quarter to 100, and in another to 50, leagues off shore; and that at the medium rate of half a mile per hour.

I do not pretend to decide, absolutely, the cause of this *inset* towards the shore; but there are two facts which seem to indicate that the inset into the Strait is the cause of the obliquity, at least as far down as the Canary Islands. Two Journals, cited by M. Fleurieu, the one of a ship from Cape Spartel to the meridian of Tenerife, in lat. 30°; in which the current was found to set E. 13° S.

the whole way; the other from Cadiz, direct to Tenerife, (that is, on a line a little nearer to the shore than the former,) found the current to run *east*. The direction of the shore being north-easterly, there is, of course, in both instances, a determination of the stream towards the mouth of the Strait, through a space of more than 200 leagues. The Western-Islands are, indeed, 300 leagues from the Strait; but the before-mentioned fact, of the regular and equable *set* towards it, joined to the circumstance of being in the summer season also, (July) renders it very suspicious that the cause is the same with that which inclines the water from the south-westward towards the Strait's mouth.

But to the southward of the Canary Islands and Cape Bojador, and between them and Cape Blanco, although the current points very much towards the shore, from the distance of 50 leagues off, at sea, yet it cannot be said to point much towards the Strait's mouth: for the current ran E. 14° S., whilst the coast lies about N. 35° E. This is given on the authority of the *Solide's* Journal; and although the current is here represented to be *less to the south of east* than many others represent it, yet all are agreed concerning the fact of the current *setting very much towards the coast*.

It may be proper to state, as an additional caution, that, *at times*, the *inset* is much stronger than at others. M. D'Aprés says, that some have made the land of *Africa*, when they expected to have made *Tenerife*; and others *Allegranza*, when they

expected to have seen *Tenerife;* which are, respectively, errors of 80 and 50 leagues, in easting, in a voyage which might have been accomplished in a fortnight.

From whatsoever cause it may arise, the effects of the above drift, towards the shore, have produced numberless shipwrecks. Perhaps no other current in the ocean has ever produced so much misery to navigators and occasional passengers. It is the operation of these currents that has placed, from time to time, a number of shipwrecked captives, of all nations, in the hands of the barbarous tribes, on the western edge of the great African Desert; and who sell the survivors to the scarcely less barbarous people of Marocco. These accidents appear to owe their *immediate* cause to the covetousness of saving a little distance, by making a *straighter* course, and keeping nearer to the shore; when, in fact, their progress on the whole would be much greater if they sailed more at large, until they had passed Cape *Blanco:* for the winds are more steady and fresh, *without,* and the current *directly* in their favour, which is not always the case nearer the land.

Add to this, that the coast of the Desert being very low, cannot be seen far off: so that it happens that a ship which, by the gradual operation of the current on her course, has been carried towards the shore, arrives in the evening so near it, that had it been of an ordinary height, it might have been seen and avoided; but continuing her course during the night, runs on shore before they

are aware of the vicinity of the land, or of being in *soundings*. This seems to have been the case of Admiral Keppel, in his voyage to *Goree*, during the seven years' war: the Litchfield, of 50 guns, was lost, and her crew made slaves; and the rest of the squadron had a narrow escape.

To return to the subject of the Northern Atlantic Currents, *at large*.—As far then as *Madeira* and the *Canary* Islands, to the southward, and to an indefinite point, westward, in the ocean, the currents are known to *set* obliquely towards the coast of Africa: that is to the S.S.E., or S.E., on the westward of a line drawn from Cape St. Vincent to Tenerife; but, on the eastward of that line, that is, on the side towards the coast, it *sets* nearer east. Again, from the Canary Islands to the Cape Verde Islands, taking a line from one to the other, the current on the *west* of it, and to an indefinite distance, westward, runs to the westward, or S.W., according to the course of the trade-wind; but to the *east* of it, or towards the shore, it is not much to the south of east, and *pointing nearly towards the land*, until we arrive in the neighbourhood of Cape *Blanco*, in about lat. 21° S. This being a prominent point, whence the coast trends to the N.E. towards the Strait, on the one hand, and southward to Cape Verde, on the other, it divides the *inner* stream of current; for here it changes its direction with the coast, running somewhat to the west of south, and identifying itself with the *outer* stream.

We are now arrived to the length of Cape Verde

and its islands; a critical point, both in respect of winds and currents. For, in respect of the former, the southerly *monsoon* of the neighbouring continent of Africa, which extends northward, to a point near Cape Verde, (see page 37,) is also felt among these islands; and those who have not been aware of the cause, have supposed that the alteration in the winds, at this season, takes place in consequence of the interruption given by these islands to the course of the regular trade-winds. But it is a part of the regular system of *periodical* winds of this region, similar to the *monsoons* of the Indian Ocean.

As far as the Cape Verde Islands, the northern Atlantic current (with the exceptions before mentioned) preserves a *south-westerly* course; but when it has passed these islands, it turns slowly round towards the *south;* and afterwards, in like manner, to the *south-east* and *east-south-east;* influenced, as may naturally be supposed, by the *form* of the coast of Africa, as it seems to have been in its way to the just mentioned islands.

It is an object of considerable importance, to navigators, to ascertain the position and general extent, *breadth-wise,* of this S.E. stream. The observations and sailing instructions, that I have seen, do not coincide in this point, with the information which I have derived, from what I deem the best authorities [1]. A knowledge of the position

[1] That is to say, the journals and remarks of Captain Cook, Admiral William Bligh, and the Captains Krusenstern and Lisiansky.

of the western border of it, in particular, would prove of great use; in order that navigators might know how to avoid it, during their passages across the interval between the two trade-winds, when that interval is very wide, as in the months of July, August, and September, (that is, from 7 to 10 degrees): more especially, when the voyage is southward; because southerly winds prevail there more than others.

On the side towards the continent, this stream comes up to the coast, during the season of northerly winds; but, in the southerly season, the current towards the coast runs to the northward, and forms a separate stream, as I have already described in pages 39, 40. The reader will immediately recognise, in this south-easterly and E.S.E. stream, the one described in page 39, and which, in the fair season, passes along the coasts of Guinea and Benin.

According to the before-mentioned authorities, this current begins to change, from S.W. towards the south, immediately after passing the Cape Verde Islands, whence it becomes first southerly, and afterwards gradually winds round to the S.E., and finally to E.S.E. But it varies so slowly, that its *western border* will still be found about the meridian of St. Antonio, in latitude 8° north; from whence, turning more towards the east, the same border will again be found in about latitude 4° N., and longitude 20° W. Here, during the season of northerly winds in Guinea, we lose all traces of its south-western border, until we arrive at Captain Cook's station, opposite to Cape Palmas;

which station was in about latitude 1° 30′ N., longitude 8° W. So that through an extent of about 12 degrees of longitude, no particulars concerning its S.W. or southern border are known to me: that is to say, during the season in which it continues its course to the eastward, along the coast of Guinea, &c. For, in the season of the southerly winds, it appears to unite with the western or Equatorial stream, in the interval between the two points just mentioned: of which I shall presently speak.

But, during the season of southerly winds, (May, June. &c.) Captain Krusenstern found a S.E. current; and that strong, or 14 to 25 miles per day, far to the west of the above-mentioned border. For, in May, he first found it in lat. 2½° N., long. 22½° W., whence he traced it to 6½° N., in about 23¼° W.: and which, being over the very same ground where he and Captain Lisiansky, in November, found a northerly or a N.E. current. Whether this extension of the stream, *westward*, be the effect of its being checked on the *east* by the western stream, remains to be ascertained.

Captain Lisiansky also found the S.E. current in longitude 18½° W., and at no great distance to the northward of the Equator, (probably in 2° or 2¼°,) in the same month of May. It may be conceived to be the continuation of the same border observed by Captain Krusenstern, and the point of junction of the S.E. stream with the Equatorial, could *not be far off to the S.E.*; and seems, indeed, to render the fact of the junction in that quarter highly probable.

It is pretty satisfactorily ascertained, that the

breadth of this stream, beyond the Cape Verde Islands, is, at the least, 4 degrees; because Captain Cook's two tracks of 1772 and 1776, *through it,* were at *that* distance from each other: and it appears unlikely that the tracks were on the absolute verge, on either side. Doubtless, 4½ degrees, or more, may be taken for the greatest breadth of the *permanent* stream: and when the *inner* or *periodical* one is added to it, probably seven degrees or more; but this is confined to the space between *Cape Verde* and *Sierra Leon*, after which it is narrowed to little more than three degrees between the before-mentioned station of Captain Cook and Cape Palmas; unless it be supposed, (which I see no reason for supposing,) that the *western part* of it joins the Equatorial Stream, at all seasons.

But that the WHOLE of it does join that stream, during the season of south-westerly winds, appears to me *almost certain:* otherwise, how is it to be accounted for, that the Grenville (as before mentioned,) which had entered the S.E. (or rather E.S.E.) current, two days before, and had advanced within 30 leagues, S.W. by W., of Cape Palmas, was driven back, by an opposing current, which first *set* south, then S.W., and finally W.S.W. and westerly, and so continued, till it had carried them, in all, 390 miles? One may conclude that the *gyration*, just described, was the effect of the *meeting* of the eastern border of the E.S.E. stream with the westerly (or rather W.S.W.) stream, from within Cape Palmas: and which received its direction from the land to the

eastward of that cape, as I have already most fully stated, in pages 119, 121, to which I beg leave to refer. It is obvious that the westerly current left no space between it and the shore of Cape Palmas, for the passage of the E.S.E. current that way; which, therefore, was compelled to turn back, in the manner described.

A great acceleration of rate of the western or Equatorial Current, appeared soon after: for, after the Grenville had experienced a rate of 44 miles in the first day of the south-westerly current, it increased to 77 and 79, during the two succeeding days; and, on the third, was 62: but, on the following days, fell to 35 and 32, the ordinary rate of the Equatorial Stream. Now, this great increase of 77 and 79, happened between the degrees of 11 and 14½ west longitude; and the eastern edge of the E.S.E. stream was *opposed* in about longitude 9° west. The breadth of this E.S.E. stream has been taken above, at about 4½ degrees, (page 297;) but as the two streams meet each other with a great degree of *obliquity*, (the one running E.S.E., the other W.S.W.,) the breadth of the former must be reckoned *diagonally* at the place of meeting; whence it cannot be taken at less than 6½ degrees. Consequently, the influx of the *western edge* of the E.S.E. stream into the Equatorial may be looked for in about 15½° of west longitude, since the *eastern edge* was in 9°.

This will accordingly be found to agree, generally, with the position in which the great *acceleration* took place: for the junction, being supposed to

have been between 9 and 15½ degrees, whilst the increased rate took place between 11 and 14½° ; and what is so likely to increase the rate as the sudden accession of such a stream to the Equatorial Current? To me, the circumstances, collectively, are in *the next degree to absolute proof* of the junction of these streams *in this place*, during the season of the S.W. *monsoon*.

To this is to be added, that Captain Lisiansky, who recrossed the Equator, in his way home, near the middle of May, says, that this took place in longitude 16° 48′ west; "having a *pretty strong* WESTERLY current, which *soon* changed to SOUTH-EAST, and continued to latitude 9° north."

As the Grenville's Journal describes the westerly current, in about one degree N. in this place, and probably was not at the extreme northerly verge of it, one cannot expect that Captain Lisiansky fell into the S.E. (or E.S.E.) current, below latitude 2° or 3° N. In a general point of view, this is not unsatisfactory ; as it gives a point in the S.E. current in a position not known before. But it must be remarked that he places this border of it rather more to the west than others, when he reports it to continue to lat. 9° N. and long. about 25° W.

APPENDIX.

I.—OBSERVATIONS ON A CURRENT

THAT OFTEN PREVAILS TO THE WESTWARD OF SCILLY, ENDANGERING THE SAFETY OF SHIPS THAT APPROACH THE ENGLISH CHANNEL; AND NOW GENERALLY KNOWN BY THE NAME OF RENNELL'S CURRENT.

[WITH THE AUTHOR'S LAST ADDITIONS.]

Read before the Royal Society, June 6th, 1793.

It is a circumstance well known to seamen, that ships, in coming from the Atlantic, and steering a course for the English Channel, in a parallel somewhat to the *south* of the Scilly Islands; do, notwithstanding, often find themselves to the *north* of those islands: or, in other words, in the mouth of St. George's, or of the Bristol Channel. This extraordinary error has passed for the effects, either of bad steerage, bad observations of latitude, or the indraught of the Bristol Channel: but none of these account for it satisfactorily; because, admitting that at times there may be an indraught, it cannot be supposed to extend to Scilly; and the case has happened in weather the most favourable for navigating, and for taking observations. The consequences of this deviation from the intended track, have very often been fatal; particularly in the loss of the Nancy packet, in

our own times; and that of Sir Cloudesley Shovel, and others of his fleet, at the beginning of the present century. Numbers of cases, equally melancholy, but of less notoriety, have occurred; and many others, in which the danger has been imminent, but not fatal, have scarcely reached the public ear. All of these have been referred to accident; and therefore no attempt seems to have been made to investigate the cause of them [1].

I am, however, of opinion, that they may be imputed to a specific cause; namely, a current; and I shall therefore endeavour to investigate both that and its effects, that seamen may be apprised of the times, when they are particularly to expect it, in any considerable degree of strength; for then only it is likely to occasion mischief; the current that prevails at ordinary times being, probably, too weak to produce an error in the reckoning, equal to the difference of parallel between the south part of Scilly, and the track that a commander, prudent in his measures, but unsuspicious of a current, would choose to sail in [2].

It seems to be generally allowed, that there is always a current setting round the Capes Finisterre and Ortegal into the Bay of Biscay [3]. This I have the authority of Captain Mendoza Rios, a Fellow of the Royal Society, and an officer in the royal navy of Spain, for asserting. Besides, such an intimation was amongst the earliest notices that I received concerning matters of navigation,

[1] In December, 1758, the *Belliqueux*, a French sixty-four, was carried to the entrance of the Bristol Channel and captured. She had escaped from Louisbourg. And, in about 1797, the Terrible, Sir Richard Bickerton, was carried to the northward of Scilly.

[2] It may be remarked, by the way, that the true latitude of the present light-house on St. Agnes's Island, is 49° 54′; and that of the most southerly part of the whole group of islands and rocks is 49° 52′. This is according to an advertisement given out by the Trinity House, in 1792.

[3] It has since been discovered that the current to the west of Scilly has a *rotatory* motion; falling again into the *eastwardly* current which enters the Bay by Cape Finisterre: so that the northern part of the stream will set to the N.W. and W.N.W.; the southern part to the west and S.W.

when on board a ship that sailed close along the north coast of Spain, in 1757. The current, then, is admitted to set to the eastward along the coast of Spain, and continues its course, as I am assured, along the coast of France to the north and north-west[1]: and, indeed, any body of water once set in motion along a coast cannot suddenly stop; nor does it, probably, in any case, lose that motion, until, by degrees, it mixes with the ocean.

The original cause of this current I apprehend to be the prevalence of westerly winds in the Atlantic, which, impelling the waters along the north coast of Spain, occasion a current in the first instance. The stronger the wind, the more water will be driven into the Bay of Biscay in a given time; and the longer the continuance of the wind, the farther will the vein of current extend.

It seems to be clearly proved that a current of water, after running along a coast that suddenly changes its direction, (as happens on the French coast, at the promontory south of Brest,) does not change its course with that of the shore, but that the main body of it, at least, preserves, for a considerable time, the general direction which it received from the coast it last ran by. In some instances, after being projected into the sea, currents *never* again approach the shore; but preserve, to a very great distance, nearly the direction in which they were projected; as well as a considerable degree of their original velocity and temperature. The Gulf-stream (of Florida) is a wonderful instance of this kind, which, originating in a body of *pent-up* waters in the Gulf of Mexico, is discharged with such velocity through the Strait of Florida, that its motion is traceable through the Atlantic to the Bank of Newfoundland, and may possibly extend much farther[2]. This being

[1] Since proved by Captain William King, R.N. as shown hereafter.

[2] See Sir Charles Blagden's observations on the heat of the Gulf-stream, in the Philosophical Transactions, Vol. lxxi. page 334. It is now well known that this stream generally reaches to the Azores, and occasionally to the coasts of Europe, as shown in the preceding work.

therefore the case, we can have no difficulty in conceiving that the current of the Bay of Biscay continues its course, which may be about N.W. by W., from the coast of France to the westward of Scilly and Ireland.

At ordinary times its strength may not be great enough to preserve its line of direction across the mouth of the English Channel; or, if it does preserve its direction, it may not have velocity enough to throw a ship so far out of her course as to put her in danger. But that a current prevails *generally* there can be little doubt; and its degree of strength will be regulated by the state of the winds. After a long interval of moderate westerly gales, it may be hardly perceptible; for a very few miles of northing in the twenty-four hours will be referred to bad steerage, or some other kind of error; but after hard and continued gales from the western quarter, the current will be felt in a considerable degree of strength; and not only in the parallel of Scilly, but in that of the south-west coast of Ireland likewise.

Our observation of what passes in the most common waters is sufficient to show how easily a current may be induced by the action of the wind, on the water contiguous to a bank, when the wind blows *along* it. In a canal of about four miles in length, the water was kept up *four inches* higher at one end than at the other, by the mere action of a moderate breeze of wind along the canal. This was an experiment made and reported to me by my much lamented acquaintance, the late Mr. Smeaton [1]. We know also the effects of a strong south-west, or north-west wind, on our own coasts; namely, that of raising very high tides in the British Channel, or in the Thames, and on the eastern coasts, as those winds respectively blow, because the water that is accumulated cannot escape quick enough, by the Strait of Dover, to allow of the level being preserved. Also, that the Baltic is kept up *two feet* at least, by a strong

[1] In a gale of wind, which happened in the year 1823, a part, or *Reach*, of the *Grand Junction Canal* was raised 21 inches.

N.W. wind of any continuance ; and that the Caspian Sea is higher by *several* feet, at either end, as a strong northerly or southerly wind prevails. Therefore, as water pent up, in a situation from which it *cannot escape*, acquires a higher level, so, in a place where it *can escape*, the same operation produces a current; and this current will extend to a greater or less distance, according to the force with which it is set in motion; or, in other words, according to the height at which it is kept up by the wind[1].

It may possibly be asked, why a similar current does not prevail in the English Channel, from the same westerly winds? To this I answer, that the increased height and velocity of the tides, during the prevalence of such winds, prove that a part, at least, of the same effect which happens in the Bay of Biscay, is produced in the Channel; and I have little doubt, that there is, in fact, a current also; but that, as it is blended with the common tide, the effect on the senses is lost: for it may appear in the form of only a *stronger* flood tide, or a *weaker* ebb, than at other times. Whereas the Bay, a wider space, and of a different form, allows a freer scope to the tides than the English Channel does: it being high water nearly at the same time, all over the Bay; but varying in the Channel, at least five hours. And it may be concluded from analogy, that, if no such phænomenon as a tide existed, a current, though less strong than in the Bay, would be perceived in the English Channel.

[1] An opportunity has occurred of proving the fact of the elevation of the Ocean by the operation of a periodical wind (or monsoon) in a situation where the coast, by forming a deep recess, (the Bight of Benin) favours the process. The particulars have been described in the preceding work, pages 146, 7.

Captain F. W. Beechey, of H. M. ship Woolwich, has also stated, that at *Bengasi*, on the northern coast of Africa, at the entrance of the *Greater Syrtis*, (Gulf of Sidra), the N.W. winds *generally* raised the level of the sea two or three feet, and still more if they continued any length of time.

He also states that, within the Gulf of Syrtis itself, the strong N.W. winds *appeared*, for he could not *ascertain* the fact, to raise the level at times four or five feet.

Of the Bay of Biscay it may be observed that, by reason of its form, and exposure to the reigning winds, which are often violent, and which pass over a vast expanse of water, there is no part of the ocean, familiarly known to us, whose circumstances are, in any degree, similar to it. It ought not therefore to surprise us, if we find that it differs, in any particular, from other seas. Seamen have remarked its uncommon degree of agitation, in stormy weather; but this has not, as far as I know, been properly accounted for. May it not be owing, generally, to the same cause as that which produces the current? and at times, to the very current itself? With respect to the first—the waves of a deep bay or gulf, when the wind forces the water into it, will meet with a resistance in the land at the head of it, which must occasion a reverberation, that will render the surface of a great part of the Gulf more unquiet, than when there is an opening at the end, to allow the undulatory motion a freer scope. What is said here, is exemplified on a small scale, by Mr. SMEATON's very ingenious manner of quieting Ramsgate Harbour. (See his Tract on that Harbour, page 45.) And with respect to the second cause—the effect of a current running to windward, in producing a short, hollow, and therefore dangerous, wave, is pretty well known. Accordingly, at seasons when the current runs strong, and the wind blows fresh from the north-west quarter, this cause must also contribute to the agitation of the waters in the north part of the Bay[1].

It is quite uncertain at what interval of time, from the commencement of strong westerly gales, in the Atlantic and Bay of Biscay, the current may operate on the tracks of ships, near Scilly; for we are not possessed of *data* re-

[1] How far the reverberatory motion may extend, I know not: but it is certain that an undulatory motion impressed on the sea by the wind, will extend to a prodigious distance; and even into a region where a different wind prevails: as for instance, a swell raised by a strong gale, at south or south-west, in the track of variable winds, has been felt, very far within the limits of the south-east trade-wind, in the Indian Ocean.

quisite for determining it. If we were to conceive a current, originating on the coast of Spain, and afterwards disturbing the courses of ships, on the west of Scilly and Ireland; this would require too much time, to agree with one of the instances which I mean to adduce: although it is probable that this may be nearly the effect at ordinary times, and when the westerly winds blow moderately. But as, in one striking instance, it appears that the current operated in a very remarkable manner, on the ship's course, on the fourth day after the commencement of the gale, in the quarter where the ship was; the cause should rather be looked for, in the *sudden* and *great accumulation* of water, in the Bay of Biscay[1]: otherwise there is no accounting for the sudden appearance of the current. And the very act of accumulation, causing an indraught there, will consequently be a current round the Capes Finisterre and Ortegal, towards the Bay. Be the exact cause, however, what it may, it no doubt originates in the Bay, by the action of strong westerly winds; the prevalence of such winds will therefore be the *signal* for the appearance of a current between Ushant and the south-west coast of Ireland: for though the cause can only be guessed at, the effect is too well ascertained, to remain in doubt.

I shall now adduce the facts, on which the idea of the existence of a current is founded.

In crossing the eastern part of the Atlantic, in the Hector East-India ship, Captain Williams, in 1778, we encountered, between the parallels of 42 and 49, very strong westerly gales; but particularly between the 16th and 24th of January, when, at intervals, it blew with uncommon violence. It varied two or more points, both to the north and south of west, but blew longest from the northern points; and it extended, as I afterwards learnt, from the coast of Nova Scotia, to that of Spain.

We arrived within 60 or 70 leagues of the meridian of

[1] See the communication from Captain William King, hereafter.

Scilly, on the 30th of January, keeping between the parallels of 49 and 50; and about this time we began to feel a current, which set the ship to the north of her intended parallel, by near half a degree, in the interval between two observations of latitude; that is, in two days: and the wind, ever afterwards, inclining to the south, would not permit us to regain the parallel; for, although the northern *set* was trifling, from the 31st until we arrived very near Scilly; yet the wind, being both *scant* and *light*, we could never overcome the tendency of the current. Add to this, that the direction of the current, being much more *westerly* than *northerly*, we crossed it on so very oblique a course, that we continued in it a long time; and were driven by it, as it appears, nearly 30 leagues to the west: for we had soundings in 73 fathoms, in the latitude of Scilly, and afterwards ran 150 miles, by the log, directly east, before we came the length of the islands. In effect, in running 120 miles, we shallowed the water only nine fathoms.

We not only were sensible of the current by the observations of latitude, but by *ripplings* on the surface of the water, and by the direction of the lead line. The consequence of all this was, that we were driven to the north of Scilly; and were barely able to lay a course through the passage between those islands and the Land's End.

Having no time-keeper on board, we were unable to ascertain the several points in this part of our track, and therefore can only approximate our longitude; and that but very coarsely. But according to what we learnt from our soundings, and from a vessel which had only just entered the current, it may be concluded, that the current, at times, extends to 60 leagues west of Scilly; and also runs close on the west of those islands. However, the breadth of the stream may probably be little more than 30 leagues; for we crossed it, as has been said, very obliquely; and, perhaps, in the widest part.

The journal of the Atlas East-India ship, Captain Cooper, in 1787, furnishes much clearer proofs, both of the exist-

ence of the current, and of the rate of its motion: for having time-keepers on board, Captain Cooper was frequently enabled to note the difference between the true and the supposed longitude; and it may be said, that this journal, by the means it affords of ascertaining the current, is highly valuable; as containing some very important facts, and which might have been entirely lost to the public, had not Captain Cooper marked them in the most pointed manner.

I shall proceed to state, in abstract, the most important of the facts recorded in the journal.

The Atlas sailed with a fair wind, and took her departure from the Isle of Wight, on the 25th of January, 1787; and on the 27th had advanced 55 leagues to the westward of Ushant; when a violent gale of wind began at south, and, about 11 hours afterwards, changed suddenly to the westward. The gale continued through the four following days; on the 28th it was generally W. by S., and W.S.W.; on the 29th, S.W. by W., or more southerly; and on the 30th and 31st, S.S.W., to S.W. by S.[1].

During this long interval, the ship was generally *lying to;* and with her head to the N.W. On the 1st of February the wind abated, but still blew from the south-westward; and the ship was kept to the north-west. The stormy weather returned again the following day, and continued, with little intermission, until the 11th; blowing from all the intermediate points, between south and W.N.W.; but chiefly, and most violently, from the W.S.W., and S.W. At intervals, on the 8th and 9th in particular, the journal remarks, that "*it blew a mere hurricane.*" On the 11th, the weather growing more moderate, and the wind favourable, the ship proceeded on her course, southward; being then two degrees and a quarter of longitude to the west of Cape Finisterre, by the reckoning; but by the time-keepers, more than *four degrees and a half.*

After the above abstract of the proceedings of the ship,

[1] In this, as well as in the former statement of the winds, I have allowed for the variation of the compass; that the application of it, to the quarter of the heavens, and to the chart annexed, may be more easy and clear.

I shall subjoin the following particulars; which are the most in point, to the purpose of the present discussion.

On the 27th, at noon, soon after the gale commenced, the longitude, by reckoning, agreed within 14 minutes of that shown by the time-keepers; the latter being the most westerly. This difference alone might well have arisen from an error in the log, or even in the position of the needle point on the Isle of Wight, from whence the departure was taken; but it may also be owing to the westerly current, whilst the ship remained in it, on the 27th; if we admit that such a current prevails at all times, though in different degrees of strength. Here it is proper to remark that, in delineating Captain Cooper's track on the chart, I have scrupulously adhered to the result of each day's work, of the reckoning, as I find it in his journal; contenting myself with inserting my own observations on the track in this paper only; where they cannot mislead.

The longitudes pointed out by the time-keepers on the 28th, 29th, and 30th, show that the increasing though trifling differences, between the true longitude, and that by the dead reckoning, had amounted to 24 minutes only, on the 30th. At this time the ship was about 24 leagues to the W.S.W. of Scilly; and at 5 or 6 leagues to the S.S.E. of this position, (that is, at 25 leagues S.W. by W. from Scilly,) they had soundings at 70 fathoms. This last particular is mentioned to prove that the longitude shown by the time-keepers (8° 28′ west from London) was nearly the longitude in which the ship really was, on the 30th of January. That of St. Agnes (Scilly) is taken at 6° 46′.[1]

The Atlas was now entered into the stream of the same current which occasioned so much delay to the Hector; but the course of the Atlas, being opposite to that of the Hector, it facilitated her progress; and also carried her clear of the south-west coast of Ireland.

[1] Allowance must be made for the difference between the *assumed* longitude of Scilly, 6° 46′, and the *true* longitude, 6° 20′. The latter being established, since the date of this tract, by the Grand Trigonometric Survey and subsequent observations.—Ed.

On the 31st, the time-keepers showed that the ship had been *set* very considerably to the westward of the reckoning; and by the 2d of February, at three in the afternoon, it appeared that she had been *set* two whole degrees of longitude to the west of the reckoning, since the 30th at noon; that is, in the course of 51 hours. (Here it may be proper to remark, that I have, throughout, reckoned according to *sea time;* that is, the day commences at noon.)

On the 3d of February, at noon, the time-keepers showed a farther *set,* of 23 minutes of longitude, more than the reckoning gave, in the interval since the last observation, which was 45 hours; so that, since the 30th of January, four days only, the ship had been carried by the current no less than two degrees and twenty-three minutes; and since the 27th, when the gale began, 2° 32′ of longitude; amounting, in these parallels, to ninety-nine marine miles. But here the current appears to have totally left them; and it is very probable that it even ceased before the time of observation on the 3d; for the succeeding observations of the 5th, 6th, 7th, 9th, 10th, and 11th, although the strong westerly gales continued, come so near the longitude by the reckoning (deduced from the observation of the 3d) that the differences, which are sometimes to the east, and at other times to the west, may be with more propriety ascribed to the errors of the log than to a current; as may be seen by the two tracks on the chart. We may therefore conclude, that the current did not cease at the very point of time, when the observation of the 3d was taken, but probably some time before.

It appears then that the Atlas experienced a westerly current, from a point about 24 leagues to the W.S.W. of Scilly, (if not earlier,) to four degrees of longitude west of the meridian of Cape Clear[1], in the parallel of 51°; where its effects were no longer perceptible. And as no current

[1] At the time this tract was written, Cape Clear was reckoned to be in long. 9° 15′ from London. Its latitude is now given as 51° 24′ 55″, and its longitude from Greenwich 9° 29′ W.—Ed.

was felt in the track southward on the 11th; nor in any part of the track to the north-west, between the 3d and 10th; although it was felt nearly in the same line of direction between the 1st and 3d; it may be inferred that the stream goes off to the north-west, between the aforesaid track and the south-west coast of Ireland. It is much to be regretted that no observations appear on the 12th and 13th; which would have been decisive of its course.

I come now to two particulars of the case, which I confess perplex me exceedingly. The first is, that the current was felt, apparently in its full strength, on the fourth day after the commencement of the gale, in the place where the Atlas was, and which began at south, then changed suddenly to the west and W.S.W., and afterwards fixed in the S.W. quarter. This gale was felt between the 48th and 50th degrees of latitude, and, no doubt, extended its effects very far to the south and west; but what the state of the winds had been in those quarters, previous to the 27th of January, we are ignorant. The winds in the English Channel had been easterly for three days preceding the gale: the fourth day preceding, there had been strong gales at S.W.; and the five days preceding *that*, there had been chiefly light winds at west. According to this state of facts, we can only suppose that the current originated from a vast body of water, pent up in the Bay of Biscay, by violent gales of wind; first from the southward, eleven hours; then from a point or two to the south of west; and lastly, at south-west. We are not to consider the water of this current, as having made the circuit of the Bay of Biscay; but as the *collective body* of *pent-up* waters in the Bay, running off along the S.W. coast of Britanny, and thence to the north-westward [1]; preserving nearly the direction it had acquired, by running along that coast. And it may be conceived that the frequent recurrence of westerly winds keeps up a constant current in the Bay,

[1] See the communication of Captain William King, hereafter.

and to some distance beyond it; although, during the longest intermissions of these winds, the current may become so slow, as to be scarce perceptible.

The second particular which perplexes me, is, that no northern *set* is indicated by Captain Cooper's journal: that is to say, by the mode in which each day's log is wrought; and which, in the formation of the chart, as is said before, I have strictly adhered to. It indeed appears to me very wonderful that no northing should appear, when it seems to be the very same kind of current which carried the Hector so far to the northward. It is certain that the state of the weather was such as to preclude those nice attentions to the reckoning, which might enable us to detect any small differences, between the latitude by account and that by observation: although the western *set* was too considerable to escape notice, and may even have been more than the statement sets forth. I cannot, therefore, by any means admit that there was no northing in the current through which the Atlas passed; first, because they had not observations of latitude, regularly; and lastly, because, on the 31st of January, when *lying-to*, 36 miles are allowed for 20 hours' *drift*, to the north-west; which appears to me excessive. On that day they had no observation of latitude, and on the following day, the observation showed two miles northing; which however proves nothing. Again, on the succeeding day, (the 2d) in a most important point of the track, there was no observation of latitude.

In the Hector, precisely in the same track, and at the same season of the year, the current had, as has been observed, a considerable degree of northing in its course. On two days it was about 12 miles, each; on another day 13, and on two others, 9, and 8; and this, in weather very favourable for keeping a reckoning, and with observations of latitude on every day save one; not to mention the strong circumstances of a visible *set* to the northward, indicated, as well by the lead line, as by the rippling on the

surface of the water. It is in the nature of currents, to expand their streams or columns of water, after being projected into the ocean; and therefore, according to this law, the middle part of the stream should preserve its original course in a greater degree than the borders of it; so that the middle part may run to the N.W. by W., whilst the eastern border may run more *northerly*, and the western border more *westerly*. It is certain that, in the Hector, we felt the northerly current much stronger close on the west of Scilly than farther out; and it appeared by the distance we ran, after sounding in 73 fathoms, that the current must have set much more *westerly* than *northerly*, the whole time[1].

The following remarks obviously occur, on the effect of this current.

1st. Whatever may be the breadth of the stream, (which is at present unknown) if a ship crosses it *very obliquely*, that is, in an E. by S., or more southerly direction (as may easily happen, on finding herself too far to the northward, at the first place of observation, after she gets into the current,) she will, of course, continue much longer in it, and will be more affected by it, than if she steered more directly across it. She will be in a similar situation, if she crosses it with light winds; and both of these circumstances should be attended to. And if it be true, as I suspect it is, that the eastern border of the current has a more northerly direction than the middle of it, this also should be guarded against. I conceive also, that the stream is broader in the parallel of Scilly, than farther south. And here we may remark, that those who, from a parallel south of Scilly, have been carried clear of it to the north, when approaching it in the night, may esteem themselves fortunate that the current was *so strong*; for had it been weaker, they might have been carried on the rocks.

2d. A good observation of latitude, at noon, might be

[1] See the remark on the rotatory motion, pages 34, 35, and a note on the same, given hereafter.—Ed.

thought a sufficient warrant for running eastward during *a long night:* yet, as it may be possible to remain in the current long enough to be carried from a parallel that may be deemed a very safe one, to that of the rocks of Scilly, in the course of such a night, it would appear prudent, after experiencing a continuance of strong westerly gales in the Atlantic, and approaching the Channel with light southerly winds, either to make Ushant, or at all events to keep in the parallel of 48° 45′, at the highest. If they keep in 49° 30′, they will experience the whole effect of the current, in a position where they can least remedy the evil: but if in 48° 45′, they are assailed by the north-west current, they are still in a position from whence a southerly wind will carry them into the Channel. But all ships that cross the Atlantic, and are bound to the eastward of the Lizard, had better make Ushant, under the above circumstances, in times of peace. Or, at all events, why should they run in a parallel, in which they are likely to lose ground?

3d. Ships, bound to the westward, from the mouth of the Channel, with the wind in the south-west quarter, so that it may appear indifferent which tack they go on, should prefer the *larboard* tack; as they then will have the benefit of the current.

4th. I understand that the light-house of Scilly is either removed, or to be removed to the south-west part of the islands; or of the high rocks. This is certainly a wise measure; as the light should be calculated more particularly for ships that have a *long* than a *short* departure; like those from any part of the European coasts, to the northward, or eastward. The light-house ought also to be built very lofty. I am sorry to remark, that, as far as my observation has gone, this light has never appeared clear and bright, as a light to direct ships ought to do [1].

5th. It would be worth the attention of Government (in

[1] This refers to the times anterior to the year 1778. The present light-house is a capital one, and it exhibits brilliant revolving lights.—Ed.

my humble opinion) to send a vessel with time-keepers on board, in order to examine and note the soundings between the parallels of Scilly and Ushant, at least; from the meridian of the Lizard Point as far west as the moderate depths extend: I mean such as can be ascertained with exactness, in the ordinary method of sounding. I have reason to suppose that our chart of soundings is very bad; and indeed, how can it be otherwise, considering the imperfect state of the art of marine surveying, at the time when it was made? A set of time-keepers will effect more, in the course of a summer, in the hands of a skilful practitioner, than all the science of Dr. Halley, during a long life; for who could place a single cast of soundings, in the open sea, without the aid of a time-keeper? The current in question must have disturbed every operation of this kind. It should be the task of the person so employed, to note all the varieties of bottom, as well as the depths; the time of high and low water; setting of the tides, and currents, &c. Such a survey, skilfully conducted, might enable mariners to supply the want of observations of latitude and of longitude; and, of course, to defy the current, as far as relates to its power of misleading them [1].

6th. It is certain, that the current in question may be somewhat disturbed by, or rather will appear to be blended with, the tides, at the entrances of the English and St. George's Channels; but it is obvious that the current will have the same effect, in setting a ship out of her course, as if no tide existed; because, whatever effect one tide may have, the next will nearly do away. But there are two particulars well worth ascertaining; and these are, first, the point at which the two sides of St. George's and of the English Channel separate, on the west of Scilly; and secondly, what degree of northing one of the streams has

[1] These remarks of the Author have been frequently quoted by other writers; and they probably had a strong effect on those enlightened members of our naval administration to whom we owe the present excellent surveys of the Channel, &c.—Ed.

more than the other. Because a ship, in approaching Scilly, from the west, on a flood tide, and keeping in a parallel which may be to the *north* of the point of separation of the two tides, (and consequently in the tide stream of St. George's Channel) may be thrown too far to the north; although, had she been far enough to the west, to receive the effect of the next ebb, this temporary and alternate derangement of the course, would have had no ill effect, or even have been noticed. But admitting that a tide, with any degree of northing in it, does take place, a little to the west of Scilly; this will furnish an additional reason for keeping in a southern parallel.

2.—SOME FARTHER OBSERVATIONS ON THE CURRENT

THAT OFTEN PREVAILS TO THE WESTWARD OF THE SCILLY ISLANDS.

Read before the ROYAL SOCIETY, *April* 13, 1815.

DURING the interval of 21 years, since the Society did me the honour to receive my Observations on the Current to the westward of Scilly, more facts relating to that current have been collected; as well as observations on its effects, in different parts of its course, between Cape Finisterre and Scilly: the whole tending to a confirmation of the general system set forth, in 1793; and, in one instance, affording, perhaps, a clearer proof of the strength of the stream, in respect of its *northerly* direction, than any of those adduced on the former occasion.

In pursuing the detail of these facts and observations, I shall begin in the neighbourhood of Cape Finisterre, and proceed, with the course of the current, along the Bay of Biscay; and thence, across the mouth of the English Channel, to Scilly and the entrance of St. George's Channel.

The first three facts regard the current from the open sea, setting into the south side of the Bay of Biscay, and along the north coast of Spain; which current has been supposed, in the former Paper, to be occasioned by the prevalent westerly winds; which force the water near the shore, *into the Bay*, and along the southern coast of it. The water so displaced, would be followed of course by the adjacent water *behind* it, in the open sea; and so on,

successively, to a certain extent. These westerly winds, and not the *Gulf-stream*, extended to the coasts of Europe, (as some have supposed,) must surely be referred to, as the cause of the Scilly current.

I. The first case is that of the *Earl Cornwallis*, East India ship. The circumstance occurred on her outward passage: she was well provided with time-keepers, as most of the India ships are.

On the 12th of March, 1791, between the parallels of 43° and 44°; and at 3° 45′ of longitude west of Cape Finisterre, (about 53 leagues), this ship experienced an easterly current, equal to 26 marine miles. Her position being directly opposite to the line of the southern coast of the Bay of Biscay, it is a fair conclusion, that the current was occasioned by the cause above-mentioned; or, as seamen call it, the *indraught* of the Bay: which, it appears, extends to, at least, 53 leagues from the shore. And as the rate in this place exceeds one mile *per* hour, it may be supposed that the effect extends to a still greater distance.

It may here be remarked, that the same ship, in coming out of the *Chops* of the Channel, a few days before, was *set* 24 miles to the westward, 15 to the northward; in the course of the 24 hours: that is, 28 miles, in a direction of N.W. by W. This may be supposed to be the same stream of current, in its course from the *Bay* towards *Scilly*.

II. The second fact is, that of the *drift of a bottle*, which was thrown out of a Danish ship, (I believe, sent on discovery,) since the publication of the former Paper.

The bottle was thrown out, in lat. 44½°, long. 12° west from Greenwich: that is, about 48 miles to the N.E. of the Cornwallis's station, at the time that she began to feel the current, on the 11th March. It was taken up by a centinel on duty, near Cape Ortegal; and, as was supposed, at the moment of its driving into the surf. If this was really the fact, the bottle, according to the date of the letter contained in it, must have been carried, at the rate

of half a mile *per* hour, in the direction of about E.S.E. ½ E.; the distance was about 64 leagues[1].

The report of this circumstance was transmitted by the French consul at Corunna to the Academy of Sciences at Paris.

It may be observed, that the drift of the bottle was much to the *south* of east; whereas that of the Cornwallis was east; that is, both pointed towards Cape Ortegal or its vicinity, as if the main stream of the current was concentrated there[2].

With respect to the velocity of the current, in the present case, all, of course, depends on the time of the arrival of the bottle at the shore. It might have been thrown up long before it was seen, and washed off again by the tide or surge of the sea. The *direction*, the most important point, cannot be questioned.

III. The third fact is very simple, and perfectly conclusive. Off Cape Ortegal, at a considerable offing, Admiral Knight found the current, at the rate of one mile *per* hour, setting to the E.S.E., that is, nearly *along shore*.

The reader will immediately perceive that these three facts converge, as it were, to one point: that is, in the proof that the waters of the Atlantic flow into the Bay of Biscay, along the north coast of Spain.

It would seem that the north-westerly current by Scilly did not, at least in many cases, balance the effect of the

[1] A bottle from the ship *Catharine*, of London, was thrown out in latitude 44° long. by acc. 13° 49′, 25th of June, 1817, and was found on shore at three leagues to the southward of Cape Finisterre, 10th Nov. 1817. The course of this bottle, therefore, was somewhat more to the southward than the other.

Near the end of the month of May, in the same year, a bottle had been picked up on the same spot, which had been thrown from the ship Georgia, William Baugh, master, in latitude 49°, long. 43°. *Date omitted.*

[2] The Spanish surveyors have shown that, between Cape St. Adrian and Cape Ortegal, the currents set, with great strength, during south-westerly winds; while, at times, a powerful current sets in for the land from the N.W.—Ed.

easterly current round Cape Ortegal, and the land of Finisterre [1]. The loss of His Majesty's frigate, Apollo, with most of her convoy, may surely be attributed to the operation of this current. Captain (afterwards Commissioner,) Wallis assured me, that after having made, as he supposed, ample allowance for clearing Finisterre, yet, in the night, he had a very narrow escape from shipwreck. Very many others have been brought into the same kind of danger: so that the land of Finisterre, were it not discernible at a considerable distance; and its offing clear of rocks and shallows; and, moreover, situated in a finer climate, would prove a kind of Scilly to mariners.

I have not been able to obtain any proofs on record concerning the course of the current *round* the Bay of Biscay. I formerly collected some information from a French commander respecting it. He said, that the setting of the current along the coast of France to the north and north-west, was a fact well understood; and even acted on by many in the choice of the *tack*, on which the current gave the greatest advantage with dead winds [2].

[1] Nor, admitting an equal rate in both places, could it well be. For the current enters the Bay of Biscay in an *east* direction, but goes off from it *north-west*. So that if a ship was carried fifty miles to the N.W. from Ushant, she would have only made about thirty-five westing; but in the other case she would be carried the *whole* fifty eastward, towards the Bay and Cape *Finisterre*.

[2] Since the above was written, the Author has received the following important and satisfactory communication from Captain William King, R.N.

Returning from India, a passenger, in February, 1797, in a merchant-ship, he was captured by a French privateer. Intending to take the port of *Passage* in Spain, which is known to be near to Bayonne, in the very bight of the Bay of Biscay, [See Chart VII.] she had arrived to within four miles of the entrance, when nightfall and the want of a pilot compelled her to stand off shore, when a most violent gale of wind came on, blowing right on the shore; and which, blowing all their sails away, left them no hope of escape from shipwreck. They thus spent a miserable night, expecting every moment to be their last, and wondering at their prolonged existence: but, when daylight appeared, they found themselves so far off shore, to the N.W., that it was barely visible from the deck. Captain King remarks that the N.W.

One circumstance, and that a very striking one, in respect of this particular, is, that the soundings in the Bay of Biscay show little or no *muddy bottom* to the *southward* of the *River Gironde;* but every where to the *northward.* This seems to show that the mud of the *Gironde*, *Charente*, *Loire*, &c. &c. is all carried to the northward; and by what cause, but a northerly current? Had the motion of the sea been variable, the mud would surely have been distributed to the south as well as to the north of the mouth of the Gironde. The alluvial *embouchures* of the rivers in general here, and the positions of the banks formed by them, in the sea, point to the N. or N.W.[1]; apparently the effect of the same sea current[2].

IV. In continuation of this current, along the Bay of Biscay, I shall next mention, that Captain (afterwards Admiral) John Payne assured me that, being in His Majesty's ship *Russell*, in a severe gale of wind at S.W., and with the ledge of rocks, called the *Saintes*, not far to leeward, he was under apprehensions for the safety of the ship during a whole night: but to his surprise found himself carried clear of the danger, by a current which set the ship, in all, about seventy miles to the north-west.

V. The flowing of the tides, on the west of Scilly, cannot well be accounted for on any other supposition than that the flood is prolonged by a southerly current. The flood

current, (or, more probably, northerly,) must have been very strong, in order to have counterbalanced so great a drift.

The above seems to be a case of much the same kind with that of the *Atlas*, described in pages 308 to 312.

[1] This is more fully explained hereafter. Page 331.

[2] From a view of the chart of soundings, between Spain and Ireland, one might be led to suppose that the deep water and steep shore, along the north coast of Spain, had been *partly* occasioned by the water driven in from the Atlantic, in westerly storms along, that coast; and which had gradually worn away the matter *there*, and deposited it on the bank which extends from Bayonne to the westward of Ireland. For the bank seems to expand as it goes northward, in like manner as the current: and the water is shallower than might be expected, in proportion to the depths, farther in.

tide is known to run nine hours to the northward; but the ebb in the opposite direction, only three hours. This particular had not come to my knowledge when the paper of 1793 was written.

VI. But the most satisfactory proof, not only of the *existence* of a *northerly* current, athwart the mouths of the English and Irish Channels, but also of its *velocity* (at least during certain intervals,) is a statement in a book published in 1733, entitled Joshua Kelly's Treatise of Navigation[1], (in two volumes octavo.) This case is the more satisfactory, as it happened in a *dead calm* of forty-eight hours' continuance: so that all uncertainty, regarding the accuracy of a *sea reckoning*, allowances for *leeway*, *drift*, &c. is precluded; since the changes of position that took place, could only have been effected by the motion of the sea, either in the nature of a *current* or of a *tide:* and this latter must be placed out of the question, since the interval of time included no less a space than that in which four *fluxes*, and as many *refluxes* have their periods: so that they may well be supposed to balance each other.

" It has been observed (says Mr. Kelly[2]) by an experienced commander, who used the West-India voyages for many years, from England, (in his return from one of these,) that, in about the latitude of 48° 30′, open with our British Channel, having a good observation (of latitude) at the same time, it proving calm and smooth water, insomuch that he handed his sails, and so lay forty-eight hours. The first twenty-four hours, at noon, he observed the latitude again, with clear weather; and found by the same that he had *drove to the northward twenty miles;* which made him distrust his former observation, though his mate agreed with him; because the ship had not gone, to his knowledge, one mile: and upon review, he found that he was not mistaken. The next twenty-four hours, being still

[1] This was originally pointed out to me by Mr. John Purdy.

[2] Vol. I. p. 434.

calm, he had again another good observation; and then found himself about twenty-six miles to the northward of his last observation; which confirmed him that he was right the day before; and that this must be imputed to a strong northern indraught, or current, there. For when you come near the soundings, and till you bring Ushant south of you, on the E.S.E. course[1], *you will hardly hold your latitude;* and the general course is E.N.E. or E. by N. if but a small matter to the southward of latitude 49°. And he says, that would have been my course, if we had not met this opportunity of discovering this strong indraught; and for want of observation, (i. e. if he had not known the latitude,) must have run up St. George's Channel, or the North Channel, as many have, and still do, for want of the same information.

"After his last observation, the wind sprang up; and making allowance for the said indraught, (i. e. in his future course,) the next day he was brought into soundings; and the following day he was brought in sight of the *Lizard*, by steering to the southward of the east[2]."

It will naturally occur to the reader, that although this case gives the *northing only;* yet that, in respect of the main question, which is, the danger of shipwreck on Scilly, or of being carried into the Bristol Channel; it is sufficient to produce a conviction of the necessity of attending closely to the ship's course, when on the point of entering the English Channel, after, or during, a course of strong westerly or south-west winds. But it would, doubtless, have been more satisfactory, had the *direction* of the stream been known. Had that been *north-westerly*, as I have before supposed, the rate of velocity must have been more than a mile and a

[1] These are *compass* bearings. The magnetic variation, at that time, being about a point and a half westerly, these will be respectively E. ½ S.; N.E. ½ E.; and E.N.E. ½ N.; true.

[2] Meaning, no doubt, the E.S.E. course, by compass, as above, or true E. ½ S.

quarter *per* hour; or approaching to one and a half (the northing being twenty-three at a mean in the twenty-four hours): whilst that in the Atlas East Indiaman, recorded in a former Paper, was about one mile *per* hour, during four days, consecutively.

The statement in Mr. Kelly's book, which is, indeed, altogether more brief than could be wished, is also defective through the want of the distance sailed, from the place of the last observation for the latitude, to that from whence they saw the Lizard Point. They had their first soundings the day after that observation; and, on the following day, they saw the Lizard. His course appears to have been regulated with a view of preserving, nearly, his parallel of 49° 16′; to which he had been carried by the current. It is not likely that he sounded to any great depth: perhaps seventy fathoms; which in that parallel might have been about twenty leagues south-west from Scilly: and it does not appear that he considered himself in soundings when the calm began; which, however, it is probable, he was, although in deep water[1]. Accordingly, one may conceive that his position, *at the end of the calm*, might have been about the meridian of Cape Clear, or somewhat to the eastward of it. It must be recollected that, in running towards the Channel, after the calm, he had still to encounter the same adverse current: and that, possibly, to within thirty or forty miles of his seeing the Lizard.

But, whether his position, during the time that he was under the influence of the current, be a degree more or less to the eastward, the fact bears the same on the main question; since a ship, in crossing the stream, wheresoever it may be situated, must have been carried out of her reckoning; and thereby placed in danger; in the event of thick weather happening subsequently, and preventing their setting themselves right, by an observation of latitude.

[1] Perhaps thirty to thirty-five leagues to the west of *Ushant*, and in about 100 fathoms.

His idea of the eastern edge of the stream is worth remarking; as it approaches, in a general view, to the truth. It was that, in *about* the parallel of 49°, it approached to the meridian of Ushant. And with respect to the *direction* of the stream, as he calls it a *northern indraught*, he certainly concluded that it ran to the northward, into the St. George's or Irish Channel; brushing the west side of Ushant and the Land's End. And the effect of the current on his ship was, no doubt, such as to warrant that belief, with those whose knowledge of the subject was confined to the mere effect of setting them to the northward of Scilly, and into the mouth of the Bristol Channel.

The information contained in this statement, does not even terminate in the mere facts of the existence and force of the current. The commander of the West-India ship, is said to have made *many voyages* to and from that quarter; and his narrative shows him to have been *an observant man*. Yet *he* was ignorant of the existence of such a current, until the case occurred which has been just stated. This then, alone, may serve to show, very satisfactorily, that the current does not exist in strength, but at certain intervals: and therefore operates in a more dangerous, because a treacherous, manner.

Had it constantly prevailed, like that round the Cape of Good Hope, &c. it could not have escaped detection; and, in consequence, few or no evils would have ensued: but these effects being felt only casually, they were considered as mere contingencies, arising from wind and weather, as in other parts of the sea; and not as resulting from a fixed cause, always operating, although in very different degrees: since no person, at that time, had collected the different cases, with a view to examine and to compare them. Some, indeed, referred it to the indraught of the Bristol Channel; without considering, that if such a power existed at all, it was difficult to conceive how it could be suspended, and why it should not operate at all times.

Our navigators, in earlier times, appear to have entered the English Channel on a more southerly parallel than they have done in latter times. For, although they might have been ignorant of the real cause of the disturbance in their course, yet many of them believed that there was an *in-draught*, as they called it, into the St. George's Channel: so that one effect of the current, that is, the *northern set*, had not passed unobserved, although the *cause* was not understood: nor, of course, could it be known when to expect it. But I have also heard it remarked by sea officers, as long ago as I can remember, that "it was unaccountable, what should occasion their *running down so much distance*, in coming in with the land from the westward." I never heard, however, that there was any suspicion of a current setting to the westward.

The idea of a northern *indraught* into St. George's Channel, (but which applies equally to the current west of Scilly,) is clearly set forth in a publication by Captain Joseph Mead, in 1757; but which came to my knowledge only very lately, by the favour of Mr. Purdy; to whom I stand indebted, also, for the knowledge of the important fact of the *set* of forty-six miles, during the calm, in the Chops of the Channel.

Captain Mead first relates the case of the ship Hope of Liverpool, bound from the coast of Guinea to that port, in November, 1735. (Preface, page iii.)

"Having had a good observation, by which they found they had the Irish Channel open, the wind continued to blow strong from between the south and west, but mostly from the former. Having no other observation (of latitude) for six days, in which time they carried sail constantly, they by reckoning expected to fall in with Cape Clear; but in the following night, they fell in with the *Blaskets*." These islands and rocks are situated in lat. 52° 12′; or about 47 miles to the north, and one degree of longitude to the westward of Cape Clear.

Again (page 10) he says, that the Bristol merchant ships,

which fall in with Cape Clear, on their homeward passage (from the West Indies, &c.) shape their course from thence, with a large wind, to the high land, near *Padstow;* which is the land they choose to make, to lead them to the entrance of the Bristol Channel. That, in estimating this course, they allowed four or five degrees in the bearing, to compensate for the indraught into St. George's Channel. This angle would give about thirteen or fourteen nautic miles: and is probably what they found, by experience, to be the general amount of the *northern set*[1].

He goes on to say, that, in like manner, the safety of ships, after they come into soundings, till they reach Scilly, depended on their making *no less allowance* than the Bristol men do, in the other Channel. "For," says he, "experience informs me that, from the commencement of soundings, in lat. 49° 30′ N. to the length of Scilly, in *fair weather,* I had found the northern indraught to be six or eight miles in the twenty-four hours."

Here then, the fact of the *northern set* is a second time recognised; though without any suspicion, any more than before, of there being a *westerly set* also.

Here it may be proper to state, what appears to me to be a very important fact; although perhaps not connected with the current in question, but materially affecting the safety of the navigation between the English Channel and Dublin. It was communicated to the Author by Captain Evans, a gentleman who superintends the harbour works at Holyhead; and who has had much experience in the navigation of the Irish Sea.

All navigators, says he, in their voyage from the Land's End to Dublin, find themselves, more or less, carried to the eastward, whilst running up St. George's Channel; which is the cause of so many vessels finding themselves in

[1] Although they might not have known at that day, the *true* latitude of Cape Clear, yet it may reasonably be supposed that they knew the quantity of the *difference of latitude* between Cape Clear and the high land of Padstow; as it was so necessary to their purpose, and so easy to be obtained.

Cardigan Bay; where, in tempestuous weather, and westerly winds, many have been lost. And this he justly supposes to be occasioned by a current setting to the north-eastward.

If the stream, which occasions this disturbance in the reckonings of vessels here, be a portion of the Scilly current, it cannot well happen in any other way than by the eastern part of that current falling on the Irish coast, to the *eastward* of Cape Clear; and being thence diverted to the north-east, along the south-east coast of Ireland. This may certainly happen; and may form a part of the cause. But I conclude that the principal part of the cause is, a current *generated* on the south-east coast of Ireland, by the prevalency of south-west and W.S.W. winds; to which the position of the coast, between Cape Clear and Carnsore Point, seems particularly adapted.

This effect, from whatsoever cause it may arise, ought to be generally known; as it may produce great inconvenience and distress to those who, for the first time, make use of that navigation: and especially to such vessels as are either not calculated, or not in a state, to beat off a *lee-shore:* for the recesses of the Cardigan Bay are deep and without shelter.

It may be conceived that a current, so generated, on the south-east coast of Ireland, (and possibly augmented by a portion of the stream from the Bay,) would *shoot off* to the north-eastward, pointing towards the Bay of Cardigan; as it cannot *turn short round* so acute a point as that formed by the Cape of *Carnsore:* such being the nature of all currents, whether of water or of air. And vessels will be carried to the north-eastward, accordingly, whilst they continue in the stream of the current. The *southerly* current which passes by Dublin, enters probably into, and merges in the stream in question; as the same kind of current, on the eastern side of England, falls into that which passes the Strait of Dover, and afterwards runs along the coasts of Flanders, Holland, &c.

The use of being well informed concerning these *partial* currents in narrow seas, is obvious; since the want of such information may, in a moment, be fatal to a ship and her whole crew. This cannot be more strongly enforced than by calling to mind the circumstances under which a frigate was lost, with her crew, during the war just terminated. She sailed either from the Downs or the Thames, to the *Helder*, and ran in the night, under full sail, on one of the shoals, lying before it. Had the commander known that there is a general *set* or current from the Strait of Dover (i. e. at the *back* of the Goodwin Sand,) along the coast of Flanders, Holland, Jutland, &c., and which is estimated to be equal to twenty-five miles, on an ordinary passage to the Texel, he would not have run on, during the night; or at least without the precaution of sounding.

Again, the Britannia India ship, in 1809, was lost on the *back* of the Goodwin Sand; probably through ignorance of the *acceleration* of the same current, during a violent gale at west or south-west, and in charge of a regular pilot. A pilot would be reckoned deficient, who did not know the direction and force of the several streams of tide, at all seasons, within his province. There is a current generally, if not constantly, running up the English Channel; that is, the eastern tides are the strongest; and in stormy weather from the west, *run longer* than the western, or ebb, tides. At the same time the level of the Channel is raised two feet, or more, above that of the North Sea; and consequently the former will discharge plentifully into the latter. Here then is an *acceleration* of the current; and which men who have the eharge of piloting ships ought to have known. And who can be ignorant of the high level of the Channel, when they know that the ports in the Channel are some feet deeper in strong westerly winds, than at ordinary times [1]?

[1] Another, and more fatal example occurred in the case of the *Ogle Castle*, a private ship, trading to the East-Indies, in the year, 1818.

Although the following remarks do not apply to the *Scilly* or *Thwart* current; yet as relating to currents, that at all times affect the navigation around the British Islands, it is hoped that the utility of inserting them may atone for their being out of place.

It is proper to state, that the facts here set forth, are assumed, on the ground of *detached* notices, and not from a connected chain of observations; which could hardly have been expected. And it is also proper to be stated, that the currents here intended, appear only in the form of a portion of the ordinary stream of tide along the coast. And it is the *difference* between the degrees of velocity of the opposite streams, on the same coast, that constitutes the current in question: as indeed it cannot be manifested in any other way. An instance has just been given in the English Channel.

Where rivers form any quantity of alluvial ground, at their entrance into the sea, there, most infallibly, the direction of the *sea current* will be shown, by the arrangement of the alluvial ground; or by the sand or mud banks contiguous to it, in the sea. The process is explained in a note: and those, to whom I may not have rendered myself intelligible, may easily satisfy themselves, by observing the junction of any two streams, that are very much disproportioned to each other, in point of bulk; and in which no art has been employed to counteract the natural course of things [1].

[1] The point of junction of two rivers (or of a river with the sea, provided that the sea has a predominant stream of current,) will always form an *acute angle*, if the soil, through which they run, be not of a texture firm enough to resist the corroding power of the stream; but composed of alluvial matter, deposited by one, or both of the waters; as is ordinarily the case. This point of junction, may be either *firm alluvial land*, or a *bank* of *sand or mud*, under water; as the case may happen. And finally, the acute angle of junction will always point in the direction of the stream of the *recipient* water; be it a river or the sea.

The reason of this is, that two streams, at their confluence, have a natural tendency to *slide* into each other, as the easiest mode of effecting their junc-

In effect, the *embouchures* of rivers, situated in alluvial ground, always *point in the direction of the stream of the*

tion; and were they, either by reason of the natural solidity of their banks, or by artificial means, compelled to join at right angles, or at a very large angle, the meeting of their waters, in a case where they had any degree of rapidity, would produce an agitation, that would prove injurious to their banks, and inconvenient to the navigation.

For the sake of illustration, let it be supposed that a small river is conducted artificially into a larger one, (or into a sea which has a current along shore,) through a *cut* made through the alluvial soil; and the angle of junction to be very large, or approaching to a right angle; and without any artificial aid, to keep it in that state; the following train of consequences would ensue. (It is to be supposed, of course, that the recipient river had its bed previously enlarged, to receive the other, in order to prevent floods.)

The first effect would be, that the head of the *adjunct* river, entering with an almost perpendicular course, into that of the *recipient*, would meet with so much resistance from it, that it would be partly beaten back, and compelled to seek its way along the bank of the recipient river. This bend in its course, would induce such a pressure on the bank, at the *lower* angle of junction, as would soon wear it away; and an *oblique course* of approach, of the whole body of the adjunct stream, would commence. In the mean time, *a triangular space* of *still water* would be formed between the *original* upper angle of junction and the *new* one, occasioned by the obliquity of course: and this *still water*, as is its nature, would let drop the mud and sand which it had held suspended whilst in motion; and thus begin to form *a triangular bank*, of the same shape and extent*.

Here then the operation is commenced in all its parts: and the *triangular bank*, by its being constantly on the increase, will force the adjunct stream to borrow, still more and more, on its opposite bank; which will gradually wear away, until the *angle of junction* of the two waters becomes so acute that the adjunct stream no longer meets with any resistance from that of the recipient; but may be said to *slide* into *contact* with it. This then, is the *natural state* of the junction of streams: but after all, the point of junction will, although almost imperceptibly, move downwards; because the *triangular bank* must continue to receive additions, if left to itself. Mean time, the body of it rises by the continual depositions above the surface of the water, and becomes firm alluvial land; its *apex* being the point of junction of the two waters; and its *direction*, of course, the same with that of the stream of the recipient water.

When two streams that are nearly equal to each other, in respect of bulk, and of velocity, join; each of them, as it were, asserts *its own rights;* and

---

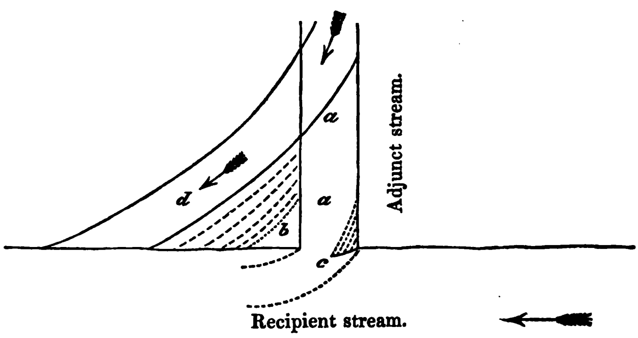
* The reader is referred, for explanation, to the sketch on the following page.

sea current. The sand, mud, or gravel banks, formed by the same current, *lie in the same direction;* and with their *narrowest* or *sharpest* point downwards.

In many places along the coast water-courses are found to terminate in long narrow lakes, with narrow sandy tracts between them and the sea, through which the water still oozes, though all appears to be *stagnant.* These also have been formed by the sea currents, and point the same way. Originally, these water-courses, or rivers, gained the sea near the place where the *head* of the lake now is; but the sea current, forming sandy alluvion, along that part of the coast, the river kept its course within it, along the former sea shore; but growing sluggish, from want of *declivity,* it formed a lake within the increasing alluvion;

the collective stream takes a direction, which is generally a mean between those of the two streams, whilst they remained in a separate state. And in like manner, the falling in of a stream that bears any proportion to the recipient river, will occasion a proportionate determination of the collective stream, towards the line of the former course of the adjunct.

It will be recollected, that all that was meant to be said here, applies to the courses of streams, through alluvial ground: and also to such as have some degree of velocity.



(*a*) Artificial cut, through alluvial ground.

(*b*) The angle of the bank first worn away.

(*c*) The commencement of a triangular bank formed by the *still water* above the point of junction.

(*d*) Progress of the adjunct stream, towards a more permanent junction.

and occasionally, in time of floods, forced open again a communication with the sea. These lakes equally prove a sea current, as well as its line of direction.

If the reader requires examples, on a large scale, the mouths of the *Senegal* and *Misisipi* rivers may be referred to. In both cases the currents are well known. And for lesser ones the rivers on the coasts of our own Islands; as those of *Christ-church*, *Shoreham*, *Newhaven*, *Orford*, *Yarmouth*, *Dublin*, &c. The small water-courses prove, equally with the large ones, the state of the current.

It is assumed, on the ground of various notices that the Author has collected, that along the western side of Ireland, occasioned by the prevalence of westerly winds, the preponderance of the stream is northwards[1]: that it turns round the north end of the Island, (or at least a part of it does,) and thence southward, along the eastern coast: probably the whole way to Carnsore Point; but certainly past Dublin. The effect of a southerly current, or prevailing southerly tide, over the northern, is visible in the present *outfall* of the Liffey; and still more in the traces of the former one; previous to the erection of the *long wall:* both having an inclination to the south. And possibly, the *direction* of the wall has itself occasioned a part of the present difficulty, arising on the matter of the pilotage.

And here I beg leave once more to quote Captain Mead; who, speaking from his own experience, says, (page 11) "on the western coast of Ireland, off the *Skelligs*, the *northern indraught* was not less than four leagues in twenty-four hours, even in *moderate* gales. Also, off the western coast of *Lewis* Island, I find it stronger than in *soundings*, (that is, more than six or eight miles in the twenty-four hours); and also, off *Foul* Island, (Shetland) something weaker than the latter."

Along the south-eastern coast, from the Mizen head and Cape Clear to Carnsore Point, the Author is less in-

[1] Articles of various kinds, known to have come from the southward and South-east, are continually casting up in Galway Bay.

formed, in respect of notices from others, than concerning any other part of the coast; but having visited it repeatedly, and considered all the circumstances belonging to it, he is firmly persuaded that there is a *north-easterly* current; and that it is *this* stream, prolonged from Carnsore Point, that carries vessels to the eastward of their course, in their way up the Irish Sea. (See above, page 328.)

The same kind of northerly stream, and occasioned, probably, by the same cause, is produced on the western coast of Scotland; from whence it turns round the north end of the island, and thence southward, along its eastern side, as far as Harwich; where it falls into the Strait of Dover, or Channel Current, which comes up at the back of the Goodwin Sand.

The Channel Current has already been mentioned (page 330), and can hardly be questioned, as to its existence, when the circumstances already set forth, are considered: such as the *elevation* of the *level* of the Channel, at times, by two feet or more; the *longer continuance* of the *eastern* stream of tide than the *western;* together with the stream that runs to the north-east, from the Strait of Dover, along the whole coast of Flanders, Holland, and Jutland: and which, affording, as is said, a help of twenty-five miles, ordinarily, between the Thames and the Texel, a run of only 160 miles, or less, cannot but be referred in part to the Channel or Dover Current.

At the mouth of the Baltic Sea, the Jutland Current is joined by the *outfall* of the former; which, at all times, receives more water than it can evaporate. The collective stream then proceeds along the coast of Norway, continuing its northerly course. Off the *Naze,* it has been known to run two miles *per* hour.

Such is the general course of the stream of current, around these Islands. There are, however, many particular exceptions to be made; as happens in the case of tides, where a deep recess in the coast often disturbs the uniformity of the general course of the stream.

3.—ON THE EFFECT OF WESTERLY WINDS

IN RAISING THE LEVEL OF THE ENGLISH CHANNEL.

Addressed to the President, SIR JOSEPH BANKS, *and read before the* ROYAL SOCIETY, *June* 22, 1809.

[VIDE CHART VII.]

DEAR SIR,

IN the "*Observations on a Current that often prevails to the Westward of Scilly,*" which I had the honour to lay before the Royal Society many years ago, I slightly mentioned, as connected with the same subject, the effect of strong westerly winds, in *raising* the level of the English Channel; and the escape of the super-incumbent waters, through the Strait of Dover, into the *then* lower level of the North Sea.

The recent loss of the Britannia East-India ship, Captain Birch, on the Goodwin Sands, has impressed this fact more strongly on my mind; as I have no doubt that her loss was occasioned by a current, produced by the running off of the accumulated waters; a violent gale from the westward then prevailing. The circumstances under which she was lost, were generally these:—

In January last she sailed from her anchorage between Dover and the South Foreland, (on her way to Portsmouth,) and was soon after assailed by a violent gale between the west and south-west. The thick weather preventing a view of the *lights,* the pilot was left entirely to the reckoning and the lead; and when it was concluded that the ship

was quite clear of the Goodwin, she struck on the north-eastern extremity of the southernmost of those sands. And this difference between the reckoning (after due allowance being made for the tides) and the actual position, I conclude was owing to the northerly stream of current, which caught the ship when she *drifted* to the *back*, or *eastern side* of the Goodwin.

The fact of the high level of the Channel, during strong winds, between the W. and S.W., cannot be doubted; because the increased height of the tides in the southern ports, at such times, is obvious to every discerning eye. Indeed, the form of the upper part of the Channel, in particular, is such as to receive and retain, for a time, the principal part of the water forced in; as may be seen by the chart: and as a part of this water is continually escaping by the Strait of Dover, it will produce a current which must greatly disturb the reckonings of such ships as navigate the Strait, when thick weather prevents the land, or the lights of the Foreland, and of the North Goodwin, from being seen.

I observe in a new publication of Messrs, Laurie and Whittle, entitled "*Sailing Directions, &c. for the English Channel*, 1808," that, throughout the Channel, it is admitted by the experienced persons whom they quote, that strong S.W. winds " cause the flood tide to run an hour, or more, longer, than at common times :" or in other words, that *a current overcomes the ebb tide, a full hour :* not to mention how much it may accelerate the one, and retard the other, during the remainder of the time [1].

It is evident that the direction of the current, under consideration, will be influenced by the form and position of the opposite shores, at the entrance of the Strait; and as these are materially different, so must be the direction of

[1] It is also asserted that, in the mouth of the Channel, the extraordinary rise of the tide, in stormy weather, is ten feet: that is, at common springs the rise is twenty and in storms thirty feet.

the stream, within the influence of each side, respectively. For instance, on the English side, the current having taken the direction of the shore, between *Dungeness* and the *South Foreland*, will *set* generally to the north-east, through *that* side of the Strait. (See the Chart, No. VII.) But, on the French side, circumstances must be very different: for the shore of *Boulogne* trending almost due north, will give the current a like direction, since it cannot turn sharp round the Point of *Grisnez*, to the north-eastward; but must preserve a great proportion of its northerly course, until it mixes with the waters of the North Sea. And it may be remarked, that the Britannia, when driven to the eastward of the Goodwin, would fall into this very line of current.

There is another circumstance to be taken into the account; which is, that the *shore of Boulogne* presenting a direct obstacle to the water impelled by the westerly winds, will occasion a higher level of the sea there than elsewhere; and, of course, a stronger line of current towards the Goodwin. (See again the Chart, No. VII.)

It must, therefore, be inferred, that a ship, passing the Strait of Dover, at the back of the Goodwin Sands, during the prevalence of strong West or S.W. winds, will be carried many miles to the northward of her reckoning; and, if compelled to depend on it, may be subject to great hazard, from the Goodwin.

It will be understood, of course, that although the stream current, alone, has been considered here (in order to simplify the subject), yet that, in the application of these remarks, the regular tides must be also taken into the account. But, from my ignorance of their detail, I can say no more than that I conceive that the great body of the tide, from the Channel, must be subject to much the same laws as the current itself. The opposite tide will doubtless occasion various inflexions of the current, as it blends itself with it; or may absolutely suspend it: and the subject can never be perfectly understood without a particular attention to

the velocity and direction of the tides in moderate weather, to serve as a ground-work[1].

I am, with great respect,

Dear Sir,

Your faithful humble servant,

J. Rennell.

4.—ADDITIONAL NOTES ON RENNELL'S CURRENT.

(BY THE EDITOR.)

Among the corroborative facts, which serve to elucidate the operation and effect of *Rennell's Current*, are the numerous wrecks which have occurred on the southern and S. E. coasts of Ireland, in the vicinity of the Saltees, &c., and of which, beyond the mere catastrophe, no other particulars are known. The last of these, anterior to the present date (1832), occurred on the 23d of December 1831, and was reported, in the Wexford newspaper, as follows :—

" On Friday night, a fine brig, perfectly new, drifted on the coast of Bannow[2]; not a soul on board. The main-sheet had been carried away, and was lying over her side in the water. The iron stay or traveller had snapped, it is supposed, and she got a dreadful lurch, so that a sea washed the entire crew overboard. It appears, by her papers, that she was named *La Bonne Julié*, of Bordeaux, bound to Dunkirk. She had not drawn any water, and was perfectly sound until she struck. She had a valuable cargo of oil, with fish, and about 100 dollars in a bag. Her

[1] Messrs. Laurie and Whittle's publication allows the tides in this quarter a velocity of one mile and a half per hour, at the springs; half a mile at the neaps. The Britannia's accident happened at *dead* neaps.

[2] Between Waterford and Carnsore Point, or the S.E. point of Ireland.

captain's name was J. Barten. The gentry and water-guard instantly came forward, and used every exertion to save the cargo [1], &c."

It may therefore be fairly presumed that the brig was carried by the current, between Ushant and Ireland, and westward of Scilly, *not less than three degrees of latitude to the northward of her intended course.*

Nor can it be for a moment doubted that the melancholy loss of *La Jeune Emma*, of Cherbourg, in 1828, was mainly attributable to the operation of the current. This ship, commanded by Chacelot de Chatillon, was wrecked in the night of November the 28th. She was of about 400 tons, from Martinique, bound to Havre de Grace, with colonial produce. The vessel had, in her passage, encountered several severe gales (we presume from the S.W.), and had shipped two heavy seas. On advancing towards the English channel, the weather was hazy, and thus continued for *several days;* so that no observation could be taken, and the reckoning consequently became erroneous. At length a *lighthouse* was seen, supposed by the captain to be that of *Ushant*, and a course was shaped accordingly: but this unhappily brought the vessel to the *Cefn Sidan Sands*, within the *Bar of Caermarthen Harbour*, and she next day became a total wreck. The captain and passengers (male and female) were drowned, and from a crew of nineteen, only six were saved.

The narrative states that there is not, perhaps, a beach of this kingdom where there is a more furious sea running, during the prevalence of south-westerly winds, than Cefn Sidan Sands; nor any which has proved more imminently disastrous to those who have been so unfortunate as to have been driven on them.

The event proved that the lighthouse, which had previously been supposed to be that of *Ushant*, on the French coast, was really that of *Lundy Island*, in the Bristol Channel! The latitude of Lundy Island is 51° 10′; that of Ushant 48° 28′. The difference of latitude between the two is, therefore, 2° 42′: or 162 nautic miles: a difference surely too great to have been effected

[1] By a subsequent account, it appeared that the vessel was cast on shore with sails set, and that some bloody shirts, napkins, &c. were found on board; whence it was apprehended that some foul deed had caused the destruction of the vessel. Two other wrecks were, at the same time, on the coast.

by merely ordinary circumstances, but which may, in the absence of positive information, be assumed as a presumptive proof of the operation and strength of *Rennell's Current.*

In 1813, the *Lark*, sloop, Andrew Livingston master, was set in one day twenty-four minutes north of the reckoning, equal to one mile an hour, but the commander could say nothing as to the westing; and on coming from Bordeaux, in 1819, he was set seventeen miles north in the twenty-four hours.

On the 13th of July, 1826, the merchant-ship *Carshalton Park*, commanded by Lieutenant John Steele Park, R.N., entered upon the Bank of Soundings on the parallel of 49°, and between the meridians of 11° and 9° west. The current was then found to be setting with "*dangerous strength.*" The ship crossed it rapidly; running all the time at the rate of seven knots, but was swept 14 or 15 miles to the N.W. by W. It had been previously ascertained that no current existed, nor was any found eastward of nine degrees west. The wind was between S.W. and N.W., flying about in squalls.

At 9 *a.m.* on the 14th, Lieutenant Park made the Lizard, bearing N.E., and had the satisfaction of finding his chronometer perfectly correct.

Bottles thrown into the sea, from different points, although they afford but a vague degree of information, yet serve to show the variations and *general* operation of the stream. Of these, different notices have appeared as follow:—

Inset; Bay of Biscay.—A bottle from the schooner *Morning Star*, of Liverpool, Andrew Livingston commander, 7th of October, 1821, lat. 42° 46′ long, 13° 3′ W. Found about 29 miles to the northward of Bayonne, in the arrondissement de Dux, lat. 43° 58′, long. 1° 20′ W., and made known by the Minister of the Marine and Colonies of France, in the "*Moniteur*" of January 24, 1822. To his Excellency and the Baron Seguier, Consul-general of France in England, we are indebted for this information, and for the original document, addressed to the editor of this work.

Inset; Bay of Biscay.—A bottle from the *Carshalton Park*, 27th July, 1827, on her passage from Jamaica to London, in lat. 48° 39′, long. by chr. 10° 21′ W. (running S.E. by S. with a mo-

derate easterly wind). "Had an easterly current all the way from the Banks of Newfoundland, which has not abated yet; but I am now looking out for *Rennell's Current*, from the Bay of Biscay; for the wind has been from the westward some considerable time. "John Steele Park, Lieut. R.N."

Taken up, on the 21st Dec. 1827, on the shore of Penbron Road, near the Loire, in the Bay of Biscay, lat. 47° 19′, long. 2° 30′ W.

Inset; Bay of Biscay.—A metal cylinder, cast from H.M. Ship *Chanticleer*, Captain H. T. Austin, 3rd of May, 1831, in latitude 44° 38½′, long. 11° 4′ W.; found near Vivero, on the north coast of Spain, 12th of September following, and at about 150 miles E.S.E. from the spot where it was dropped into the sea.—(*Notice transmitted to the Admiralty.*)

Inset; Bay of Biscay.—A bottle from H.M. ship *Graham Moore*, 6th of July, 1821, in latitude 47° 47′ N., long. 7° 51′ W.; found, 15th of September, 1821, on the coast of St. Jean de Mont, arrondissement of Sables d'Olonne, department of La Vendée; and made known by the "*Journal de Paris.*" This bottle was impelled in an E.S.E. direction, the *north-westerly* current not then prevailing, and was within the influence of the tide.

Easterly Current to Bristol Channel.—A bottle from the brig *Albert*, R. L. Robertson, master, latitude 47° 20′ N., long. 22° W. 24th January, 1822, on the passage from Virginia to England, the wind then about W.N.W., and had so prevailed for two or three days; found in Rockam Bay, about four miles west from Ilfracombe, 29th of July, 1822, and attested by the agents to Lloyd's.

St. George's Channel.—A bottle from the *Osprey*, of Glasgow, Alex. M'Gill, master, homeward bound from Calcutta, thrown into the sea 1st of March, 1822, in latitude 49° 54′ N., and long. 12° 20′ W.; it was found on the shore upon the south side of Milford Haven, on the 6th of the following month, April; and the notice was thence transmitted to the Admiralty.

From Channel Soundings to the west of Scotland.—A bottle thrown from the ship *Duke of Marlborough*, by Mr. George Thone, near the Sole Bank, in latitude 48° 38′, long. 9° W.; found on the shore of Carsaig, near the middle of the south side of the Isle of Mull, 14th of April, 1831. At the time this bottle

was thrown into the sea the ship was on her passage from the Cape of Good Hope, and an allowance was made for current to the N.W. of 12 miles to the 24 hours. From the spot in which it was dropped, it seems unquestionable that the bottle was carried by the current to the west and north of Ireland, and thence, between Ila and Mull, to the place in which it was found. It has, therefore, well answered Mr. Thone's purpose of "*confirming Rennell's Current.*"

TIDE.—A bottle from the *Acasta*, of New York, A. H. Guswold, commander, in latitude 49°, long. 10° 15′ W.; picked up 3rd November, 1822, in St. Bride's Bay, near the Port of Milford.

Channel-Tide.—A bottle from the *Sir Joseph Banks*, John Williams, commander, 16th of July, 1821, latitude 49° 11′, long. 11° 28′, calm weather, and current not prevalent; found, October 5, at Dannes, on the coast of France, between Boulogne and Etaples.

Channel-Tide.—A bottle from the *Brighton Packet*, from New York to London, 1st of August, 1824, in latitude 46° 25′, long. 5° 21′; found at Alderney, at the end of the same month.

Channel-Tide.—A bottle from the *Hannah*, of Liverpool, Thomas Davey, master, latitude 49°, long. 10° 32′ W., 8th of July, 1823; found at Petten, near the Helder.—Another, from the *Elizabeth*, off Beachy Head, 23rd of August, 1822; found at *Zandwoort*, on the same coast, 12th September.—Another, from near the Old Head of Kinsale, Ireland, 22nd June, 1822; found on the same coast, near Egmont op Zee, in September.

5.—ADDITIONAL NOTES ON OTHER CURRENTS, &c. GIVEN IN THE ORDER OF THE PRECEDING ARRANGEMENT.

The LAGULLAS CURRENT.—It has been mentioned, in the Note II. page 3, that a communication had been made to Major Rennell on the existence of the *Telemaque Rocks*, upon the Bank of Lagullas. That communication is as follows:

American ship *Macedonian*, Captain Blakeman, 5th May, 1816. "At day-light, moderate and fair; wind S.W.; steering E.S.E. At 7 A. M. saw breakers on the lee-bows, bearing East; distance, by estimation, seven miles. Hauled the wind immediately, steering S.S.E., sounded 90 fathoms. At 8, saw a very extensive patch of breakers, bearing E.S.E. $\frac{3}{4}$ E., distant six miles; at half-past 8, saw another, bearing E.S.E., and being only one breaker in a small compass. At $9\frac{1}{2}$ h. all the three breakers were very distinctly seen; the first bearing E. by. N., composed of two parts; and the next, or middle one, very extensive, being, by estimation, nearly three miles in length, from E. $\frac{1}{2}$ N. to E. $\frac{3}{4}$ S., five miles distant. The southernmost breaker, very small, bore E.S.E. $\frac{3}{4}$ S.

"At 9 h. $35\frac{1}{2}$ m. the longitude, by observed distance of sun and moon, was 22° 54′ 30″, latitude by account 38° 0′ S. Depth of water, 40 fathoms. Steering S.S.E. $\frac{1}{2}$ E. at the rate of four knots. The following bearings were immediately taken:—Northernmost shoal, E.N.E. $\frac{1}{2}$ E. about five miles; middle shoal, E. $\frac{1}{2}$ N. to E. $\frac{3}{4}$ S. six miles; southernmost, S.S.E. $\frac{3}{4}$ E. three miles." [Hence the middle of the shoal may be taken at lat. 37° 57′, long. (roundly) 23°.—J. R.]

"At 12 h. the breakers all appearing in one, bearing N.E. $\frac{1}{2}$ N., distance about twelve miles; seen from the main-top, when the bearings were taken. Latitude, at noon, 38° 10′ S."

(Signed) "A. S. PAGE."

EQUATORIAL CURRENT.—A bottle from the American ship *Lady Montague*, James Poore, Master, two leagues and a half N.E. from the Isle of Ascension, (in lat. 7° 55′ S. long. 14° 23′ W.), 15th of October, 1820;—found on the Hanois Rocks, on the western coast of Guernsey, 6th of August, 1821. *Notice transmitted to the Admiralty.*

Were we, on this *remarkable* instance, to hazard a conjecture, it would be that this bottle had taken a complete western circuit through the Equatorial Current, the Caribbean Sea, and Gulf-Stream; thence to the Bay of Biscay, and to the English Channel.—Ed.

Equatorial Current.—A bottle from the ship *Osprey*, of Glasgow, in latitude 6° 13′ S. and long. 15° 35′ W., 17th of January, 1822; found in Mayaro Bay, Island of Trinidad (W. I.), 27th of July, 1822; of which notice was transmitted to the Admiralty.

Another bottle from the same ship, in latitude 5° 12′ S. and longitude 24° 40′ W., 28th of March, 1820; found 4th of February, 1821, near the eastern point of the Salines, quarter of St. Anne, Island of Martinique. Attested by the Director of the General Post at St. Pierre.

Equatorial Current.—A bottle from the schooner *Julia*, William Davidson, Master, in latitude 6° N. and long. 40° W., 6th of November, 1821; found 7th March, 1822, near the shore of Rockly Bay, Tobago.—*(Tobago Gazette.)*

S.W. Drift and Equatorial Current.—A bottle from the *Elizabeth* packet, on her passage to Brasil, September, 1808, latitude 14° 25′ N., longitude 25° West. Picked up near Martinique, by Sir Alexander Cochrane, in 1809, having been carried about 2020 miles in 224 days; being at the rate, on a westerly course, of nine miles per day.

S.W. Drift and Equatorial Current.—A bottle from the ship *Duke of Marlborough*, by Mr. George Thone, in latitude 16° 22′ N., longitude 26° 31′ W., 14th of October, 1820; found, 24th of July, 1821, at Agujero Chico, or Petit Trou, on the south coast of Hayti, and made public by Mr. James Robinson, commander of the brig *Endeavour*, of Liverpool.

Equatorial Current and Stream of the Maranon.—It has been shown by Captain Sabine, that, in 1822, after H. M. ship *Phea-*

sant sailed from Maranham, she entered the Equatorial Current, the full strength of which she had quitted to go to that place, and it was then found to be running with the astonishing rapidity of ninety-nine miles in twenty-four hours. On the 10th of September, at 10, A.M., while proceeding in the full strength of the current, exceeding four knots an hour, a sudden and very great discoloration of the water a-head was announced from the mast-head; the ship being then in 5° 8′ N. and 50° 58′ W. (both by observation), it was evident that the discolored water could be no other than the stream of the Maranon, pursuing its original impulse at no less than 300 miles from the mouth of the river, its waters not being yet mingled with the *blue* waters of the ocean, of greater specific gravity, on the *surface* of which it had pursued its course. It was running at the rate of about sixty-eight miles in the twenty-four hours.

W.S.W. Drift to Honduras.—A bottle from the *Asia*, East Indiaman, latitude 24° 59′ N., longitude 21° 26′ W. (S.W. of the Canaries), 26th of February, 1820; trade-wind light from N.E.; picked up at Calabash Kay, in the Bay of Honduras, 12th of March, 1821.

GULF STREAM, NEAR CUBA.—The Gulf-Stream, on the south or Cuba side, is, as described by Major Rennell, (page 187,) commonly weak; and it even appears that there are instances of a *counter current* running westward, all the way from the *Bahama* or *Old Channel*, along the Cuban shore. Of this we have had more than one example; but the following, with which we have been favoured by Captain Livingston, is the most remarkable. It will be observed that this occurred in the season when the stream is generally weak.

"Captain Louden, of the brig, *Peru*, in the latter part of November, 1827, being then on his passage from New Orleans to Liverpool, had made the *Iron Hills* in Cuba; shortly after noon he tacked ship to the northward and westward, about eight or nine miles off shore: next day he kept beating to windward, as near to the middle of the Strait as he could judge, and without sighting the land on either side, the wind then blowing a fresh gale from the northward; and he continued beating in the same

manner until about 8 A.M. of the second day, when, by *reckoning*, he ought to have been near the Salt Kays: but, obtaining a lunar observation, it showed, to his astonishment, his longitude to be to the westward of 83°. Supposing his observation to be erroneous, he took a second set of lunar distances, which gave a similar result. Still, however, doubtful, he stood on, and in a short stime afterwards gained soundings on the *Tortugas Bank!* The northerly gale had now abated, and he worked his vessel in, on soundings, to the northward of the Dry Tortugas. With a favouring wind he ran through the Tortugas Channel, but as light and baffling winds succeeded, he made for the Stream as it became dusk, and with such winds got through the Strait in the two following days; having, on his way, found the current very rapid along the Martyrs."

A similar anomaly has been found where it would be less expected, namely, in the waters of the *Mediterranean Sea*, which have, under certain circumstances, been found setting *westward* from the Strait into the Ocean. Although this occurs but rarely, it is certain, and worthy of future investigation.—ED.

THE FLORIDA OR GULF STREAM.—A bottle from H. M. ship *Breton*, Hon. Captain Gordon, 2d February, 1830, in the Mexican Sea, latitude 27° 50′, long. 84° 40′, the Tortugas bearing nearly S.S.E. 215 miles;—found on the 2d of June, 1830, in latitude 25° 52′, longitude 80° 9′, on the south eastern coast of Florida, near White Inlet; where there is now a settlement. (*Notice transmitted to the Admiralty.*)

Gulf-stream to the Azores.—A bottle from H. M. ship *Newcastle*, latitude 39° 12′ N., long. 63° 52′, by Mr. James Napier, master, 20th June, 1819;—found on the shore of St. George, one of the Azores, 20th of May, 1820, in about 38° 40′ N. and 28° W. (*Notice transmitted by Mr. Wm. Parkin, British Vice-Consul.*)

Gulf-stream to Ireland.—Another bottle from H. M. ship *Newcastle*, 20th of June, 1819, in latitude 38° 52′, longitude 64° 0′; found on shore on the Rosses, on the N. W. of Ireland, near the Isle of Arran, 2d of June, 1820, and attested by Mr. Nassau

Forster. *(This appears to have been erroneously attributed to H. M. ship Pique.)*

Gulf-stream to St. George's Channel.—A bottle from the ship *John Esdaile*, Henry King, commander, cast into the sea 28th of July, 1821, in latitude 36° 55′, long. 71° 50′; picked up on the sand near the mouth of the Ribble, Lancashire, 5th Dec. 1822. (This bottle, therefore, after leaving the stream, was carried to the E.N.E. towards the Welsh Coast.)

The main-mast of the *Tilbury*, (a sixty-gun ship,) burnt off Hispaniola, in the seven-years' war, was also brought to our shores, but I cannot give any time.—J. R.

TEMPERATURES of the GULF-STREAM, as found by Captain Andrew Livingston, in the year 1818.

[*See page* 266.]

	Lat.	Long.	Month.	Temperature.
S.E. of the mouth of the Misisipi, 10 leagues -			Aug. 30.	87 deg. 90
Through the Mexican Sea, to opposite Havanna			Aug. 31 to Sept. 8.	86
Thence to opposite Cape Florida			Sept. 9, 10.	86
Thence to Cape Canaveral			Sept. 11.	85
Opposite Savanna and Charleston			Sept. 13.	84
Opposite Cape Fear .			Sept. 15.	84
Opposite to Cape Hatteras, in Mid-stream -			Sept. 16.	84

TEMPERATURES of the GULF-STREAM, as found by Captain Andrew Livingston, in the year 1818.

	Lat.	Long.	Month.	Temperature.
In the Stream . . .	$35\frac{3}{4}$	72	Sept. 17.	83 deg.
Mid-stream	$36\frac{1}{2}$	70	18.	80
	37	67	19.	78
	$37\frac{1}{2}$	$65\frac{2}{3}$	20.	80
	$38\frac{1}{4}$	$63\frac{3}{4}$	21.	81
	39	$60\frac{1}{4}$	22.	78
	39	$57\frac{2}{3}$	23.	79
	$39\frac{1}{2}$	56	24.	78
	$39\frac{1}{2}$	$54\frac{1}{2}$	25.	79
	$39\frac{1}{2}$	$52\frac{1}{2}$	25.	76
	$39\frac{1}{2}$	50	26.	77
	$39\frac{1}{2}$	$47\frac{1}{2}$	26.	77
	40	$43\frac{1}{2}$	27.	75
	40	42	28.	74
	40	$40\frac{1}{4}$	28.	74
	$39\frac{3}{4}$	$39\frac{1}{4}$	29.	74
	$39\frac{3}{4}$	37	30.	75
	$39\frac{3}{4}$	$36\frac{1}{4}$	30.	74
	$39\frac{3}{4}$	35	30.	73
	$39\frac{3}{4}$	34	Oct. 1.	74
	$39\frac{1}{2}$	$32\frac{1}{4}$	1.	74
Near Flores	$39\frac{1}{4}$	$31\frac{3}{4}$	1.	74
	39	$30\frac{3}{4}$	2.	73
	39	30	2.	74
Near Fayal	39	$28\frac{3}{4}$	3.	73

The Gulf-water seems to terminate here.

By a comparison of Captain Livingston's examples with those of others, and *reduced to the same season*, it would seem that, in the part between 15° and 25° of west longitude, (the still part of the ocean,) Captain Livingston's thermometer was a degree and a half higher than the others ; that is 70° for $68\frac{1}{2}$° in lat. 38°. But in the Gulf-stream, between Cape Hatteras and longitude 50°, more particularly between that and 60°, he agrees with Williams, Pell, and Billings.

GULF-STREAM.—A TABLE OF TEMPERATURES, FROM DIFFERENT AUTHORITIES, WITH THE DIRECTION AND RATE OF THE CURRENT.

*** The maximum of Temperature is given, and the rate of velocity, for the most part, is that along the middle or strength of the Stream, but with exceptions. The commencement of the Stream is taken to be in latitude 23° 20′, longitude 84°.

	Lat. N.	Long. W.	Month.	Temperature.	Direction.	Miles	Authority.
In the Mexican Gulf . . .	$23\frac{3}{4}$°	85°			E.S.E.	31	H. M. S. Asia.
Entrance of the Strait . . .	$23\frac{1}{3}$	84	July 18th . . .		E.N.E. N.E. by E.	23 24	
Opposite to and near Havanna	$23\frac{1}{4}$	$82\frac{1}{3}$	July 20th . . .		E.N.E.	12	Captain, now Rear Admiral, Sir J. T. Rodd, H. M. S. Warrior, 1815.
Opposite Matanzas	$23\frac{1}{3}$	$81\frac{3}{4}$	July 21st . . .		E.N.E.$\frac{1}{2}$N.	14	
Between Sable Point and the Salt-Kay Bank . . .	$24\frac{1}{2}$	$80\frac{1}{4}$	July 22nd . . .	Degrees.	N.E.	48	
Opposite Cape Florida . .	$25\frac{2}{3}$	$79\frac{2}{3}$	July 24th . . .	79	North	96	
Opposite the Maternillo Bank	$27\frac{3}{4}$	$79\frac{1}{2}$	July 25th . . .	80 $79\frac{1}{2}$	North North	96 80	
In Mid-stream	$30\frac{1}{4}$	$79\frac{1}{2}$	July 26th . . .	81	North	80	
Opposite Cape Fear . . .	33	$76\frac{3}{4}$	End of April . .	78	N.E.$\frac{1}{2}$E.	60	Anonymous.
Opposite Cape Hatteras . .	35	74	End of September	76	N.E.$\frac{1}{2}$E.	55	
In Mid-stream	$37\frac{1}{4}$	71	August . . .	77	E.$\frac{1}{2}$N.	95	Captain Pell.
	$37\frac{1}{4}$	$69\frac{3}{4}$	August . . .	82*	E.S.E.	95	

In Mid-stream	$37\frac{3}{4}$	68	August . . .	81	E. by N.	51	Captain Rodd.
	38	67	August . . .	81			
	$38\frac{1}{4}$	66	August . . .	82			
	$37\frac{3}{4}$	$65\frac{3}{4}$	June	78	E. $\frac{1}{2}$ N.	61	H. M. S. Queen.
	$39\frac{1}{4}$	$64\frac{1}{2}$	August . . .	81			
	$38\frac{1}{2}$	64	July	67	E. by N.	51	Captain Rodd.
	39	$63\frac{1}{3}$	July	81*	E. by N.	66	
	$39\frac{1}{3}$	$63\frac{1}{4}$	July	81*	E.N.E.$\frac{1}{2}$E.	48	Captain Pell.
	$39\frac{3}{4}$	62	September . .	77	S.E.	21	
	$39\frac{1}{4}$	61	September . .	76	E.S.E.	30	
*** A Tabular Statement of	41	$59\frac{3}{4}$	August . . .	78			
the VELOCITIE in the STRAIT	$41\frac{1}{4}$	$57\frac{1}{2}$	August . . .	76			H. M. S. Queen.
of FLORIDA has already been	39	$57\frac{1}{3}$	August . . .		S.S.E.		
given, in page 198 and others	$39\frac{1}{2}$	$49\frac{1}{2}$	August . . .		E. by N.	44	
of TEMPERATURES in pages	40	$46\frac{1}{3}$	August . . .		E. $\frac{1}{2}$ N.	35	
271, 281, and 283.	$43\frac{1}{4}$	45	August . . .	$76\frac{1}{2}$	E. by N.	31	Captain Beaufort.
		45		76	E.N.E.	31	
	44	$45\frac{1}{3}$	August . . .	76			
	$42\frac{2}{3}$	$43\frac{3}{4}$	August . . .	73	N.E. by E.	33	Captain Rodd.
	$41\frac{1}{4}$	$41\frac{1}{2}$	August . . .		E. by N.		H. M. S. Queen.
	$42\frac{1}{2}$	40	August . . .	74			
	$42\frac{2}{3}$	$39\frac{1}{4}$	August . . .	$72\frac{1}{2}$	S.E.	28	
	$42\frac{1}{4}$	$37\frac{1}{2}$	August . . .	$74\frac{1}{2}$,5	S.E.	16	Captain Beaufort.
				76	S.S.E.	10	
	$40\frac{1}{4}$	$33\frac{1}{2}$	August . . .	75	South		
	$40\frac{1}{4}$	$32\frac{3}{4}$	August . . .	73	South	10	
Near Corvo	40	31	August . . .	72	South	10	

Temperatures of the Gulf-stream, as found by Colonel Jon. Williams.

Lat.	Long.	Month.	Temperature.
36°.50′	70°.20′	July . .	67 deg.
37.30	71.14	August . .	77
38.45	69.50	August . .	67
37.15	69.45	August . .	82
37.50	68.0	August . .	81
38.0	67.7	August . .	81
38.20	66.0	August . .	82
37.0	68.14	August . .	75
36.30	69.20	August . .	68
39.15	64.30	August . .	81
40.45	61.0	August . .	76
41.0	59.50	August . .	78
41.15	57.30	August . .	76
41.45	55.26	August . .	67
45.10	48.8	July . .	67
44.55	45.40	July . .	70
45.0	39.40	August (1800) .	69
42.45	51.30	—— .	60

HALIFAX TO THE BAY OF BISCAY.—*Bowsprit* of H. M. ship *Little Belt*, which was dismasted on the Halifax station, about eighteen months before; picked up, 18th February, 1811, near Basque Roads, in latitude 46°, long. 2° W., by the Hon. Capt. D. P. Bouverie, of H. M. ship *Medusa*, having been carried, in the eighteen months, in an eastern direction, about 2400 miles: "nearly at the rate of four miles and a half per day."

Upon this subject Major Rennell, in a private letter addressed to the present Admiral Sir John Tremayne Rodd, made the following remarks:

"Admit that the bowsprit has been eighteen months on the sea; of course (by the date) two winters and one summer: admit that the winds blow either from the *West*, the *N.W.* or the *S.W.* quarter, in that parallel, *two* days out of three; we shall have twelve months of wind from the westward of the meridian; six from the eastward of it: whence, it results, of course, that

there will be six months of westerly (that is, west of the meridian) wind, *more* than of easterly, that the bowsprit has been subject to since it has been in the water.

"If, then, there were no current in the case, the bowsprit must have been brought to the Bay by that operation of six months of westerly wind, arising on the balance of the account of winds. The distance is said to be 2400 sea-miles, whence the drift each day at a medium, on 183 days, would be about thirteen miles in a *straight line*, from Halifax to the Bay. But, as the wind must be reckoned to have blown in every direction between N.W. and South, the drift, to make thirteen miles direct, must be no less than $20\frac{1}{2}$ for each day, *circuitously*, or the difference between a *diameter* and the half of the *circumference*. It being impossible that a spar can be driven $20\frac{1}{2}$ miles per day by *any* wind, much more by all degrees of wind, as they happen; it can be brought only by the aid of a current: and, since Halifax and the Bay are nearly in the same parallel, the course of the drift, on the whole, will have been nearly East. But as two winters are reckoned during the interval, and northerly winds are known to prevail more than southerly, at that season and in those parallels; it must be conceived that the wind has drifted it more to the *south* than to the *north;* and consequently that the current must have *some northing* in it, to make up for the southern drift."

"N.B. A bottle was thrown out in 1803, in latitude 47°, long. 21° W., and came ashore $5\frac{1}{2}$ months afterwards, (between September and March,) at the Isle of Skie, Scotland. (This, probably, was first carried into the Scilly Current.)"

A *wreck*, from latitude 44°, near Halifax, was once found in the Road of Aix; and a bottle, from latitude 49°, longitude 45°, came ashore near Cape Finisterre.

DRIFT *of the* NORTH-ATLANTIC.—A bottle from H. M. ship *Isabella*, Captain Ross, in latitude, 65° 40′ N. and longitude 54° 10′ W. Land in sight, S.E. by compass, about 60 miles distant; 3rd of June, 1818, when several ice-bergs and one

large mountain of ice were near, but no perceptible current: found 17th of July, 1819, at Balnarald, North Uist, one of the Hebrides; and the notice was thence transmitted to the Admiralty.

Drift of the North-Atlantic.—A bottle from H. M. ship *Alexander*, Captain Parry, in latitude 62° 5′, longitude 54° W. 29th May, 1818; found at sea off the north-western part of the County of Donegal, on or about the 15th of July, 1819. *Notice* transmitted to the Admiralty.

Drift to Scotland.—A bottle from H. M. ship *Alexander*, Captain Parry, in latitude 59° 8′ N., latitude 52° 19′ W., 27th of May, 1818; found 28th of July, 1819, floating near the celebrated Isle of Staffa, western islands of Scotland.

Davis's Strait to Ireland.—A bottle from H. M. ship *Fury*, Captain Parry, in latitude 62° 8′, longitude 62° 27′, July 1821; found 9th March, 1822, on the Urris shore, county of Donegal. *Notice transmitted to the Admiralty.*

Easterly Drift to Ireland.—A bottle from the United States' ship *Elizabeth*, in latitude 47°, longitude 49° 10′, 15th of August, 1819; found on the coast of Rathlee, county of Sligo, and parish of Easky, Ireland, 21st of June, 1820. *Notice transmitted to the Admiralty.*

Greenland Sea to Tenerife.—A bottle from H. M. ship *Hecla*, Captain Parry, in latitude 58° 13′ N., longitude 46° 55' W., 16th of June, 1819; found on the S.E. shore of Tenerife, 29th of July, 1821, and attested by Pasley, Little, & Co.

Easterly Drift to Scotland.—A bottle from the *Sandwich* of Dartmouth, Walter Squire, Master, lying-to in a gale, latitude 50° 16′, longitude 36° 25′, 1st of June, 1821; found on the south shore of West Uist, Hebrides, 2nd of December, 1821.—*Inverness Journal.*

Easterly Drift to the English Channel.—A bottle from the *James Cropper*, from Liverpool to New York, Jan. 10th, 1824, in latitude 48° 10′, longitude 38° 5′; found at Gunwallow fishing cove, in Mount's Bay, 12th of November, 1824.

Easterly Drift to Jersey.—A bottle from the ship *Margaret* of Glasgow, Allen, Master, in latitude 52°, longitude 24°, 1st of March 1821; picked up by the Charlotte of Havre, near Jersey. (*Date not given.*)

Easterly Drift to Scotland.—A bottle from the brig *Ardent*, John Duncan, Master, in latitude 56° 53′, longitude 24° 30′, 22nd of September, 1824; found on the Sands of Dell, near the Butt of Lewis, 12th of March, 1825.

NEWFOUNDLAND CURRENTS.—The Currents which affect navigation off the southern coast of Newfoundland, between Cape Race and the Gulf of St. Lawrence, are of so extensive, peculiar, and dangerous, a nature, and so imperfectly understood, that they imperatively demand a further inquiry; for this navigation has *latterly* proved, to misinformed commanders, the most perilous in the Atlantic Ocean.

In our view of this topic, we have to consider and combine a variety of particulars. In the first instance the operation of the *Arctic Current* or water of the North-Polar Sea, which sets as described in pages 243, &c.; secondly, the *Eddy Current* alluded to by Sir John Duckworth, (note, page 30;) thirdly, the current which sets down the Strait of Belle Isle, branching from the Hudson's Bay Stream; fourthly, the copious ebb from the great River of St. Lawrence; fifthly, the counter-current along Breton Island and Nova Scotia; sixthly, the whirls, or drifts, or eddy-currents, found to the northward of the Gulf-stream; and lastly, the south-westerly stream which crosses the Grand Bank, and which meets and *opposes* the *easterly* stream, so as to divert it into the several bays of the south coast, and thus create the "*strong indraught*" into those bays, which is noticed in the book of Sailing Directions.

Before proceeding farther we shall offer some detail which will enforce the necessity of the present remarks.

Near the S.E. extremity of St. Mary's Bay, about twenty-five miles westward from Cape Race, there is a small but dangerous spot known by the name of *St. Shot's Bay*, and which has become notorious from the numerous wrecks which have been found upon it; among which the following have been remarkable.

1. The sloop *Comus*, lost in the night of the 24th of October, 1816. At ten o'clock, it was supposed, from reckoning and double altitude taken that day, that they were on the inner edge of the Green Bank; sounded and found that they were in 25

fathoms of water, the exact depth on that bank as laid down in charts which they referred to; but, for the greater safety of the ship, it then blowing very fresh, hauled her wind, with the head off shore, and stood on under easy sail. At forty-five minutes past eleven, struck on a reef of rocks, extending from the eastern head of *St. Shot's Bay* into the sea, owing "to the *amazing in-draught into the different bays*, which threw the ship out of her reckoning." The helm was immediately put down, and the sails braced aback, to get sternway, when she was unfortunately caught by a rock, on the larboard quarter, and bilged before the boats could be got out: every exertion was used to save the ship, but in vain. At the same time the weather was so foggy that little more than half the ship's length could be seen.

2. On the 10th of November, 1816, the *Harpooner*, a transport, with troops, from Quebec, was lost here. Adverse winds and thick weather had deranged the course of this vessel, and she struck on the rocks at a few minutes after nine, on a Sunday evening, when many valuable people perished.

3. His Majesty's ship *Drake*, Captain Baker, sailed from Halifax on Thursday morning, 20th of June, 1822, for St. John's, Newfoundland. The weather being uncommonly fine, and the wind favourable, she continued to steer a direct course for Cape Race. On Sunday morning it came on extremely thick, with a fresh breeze from W.S.W.; at noon it cleared up for a quarter of an hour, just giving time to get a good observation of the latitude, which agreed very well with the latitude by account. At that time the ship was supposed, by reckoning, to be ninety miles from Cape Race. At six in the evening, having run about sixty miles since noon, and finding the fog still continued, they hauled out four points, intending to have steered S.E. during the night; about half-past seven o'clock, all hands being on deck, breakers were reported to be ahead; the ship was instantly hauled to the wind; but, not being able to clear the danger on that tack, they endeavoured to stay the vessel; but, from the heavy sea, and whilst in stay, her stern took the breakers, and she immediately fell, broadside on, the sea beating completely over her; the masts were immediately cut away, with the hope of lightening the ship, as well as affording a bridge to save the crew; but without success in either point; for, in a few mo-

ments, she bilged, at which time there did not appear the slightest hope of saving a man; and though, by masterly seamanship, many were ultimately saved, the excellent captain, with some others, perished.

4. The brig *Spence*, of Sunderland, M. Wilson master, from Richibucto, in the Gulf of St. Lawrence, bound to Liverpool, with lumber, was totally lost near St. Shot's, 16th July, 1822, at four in the evening; but the crew were saved, and arrived at St. John's.

5. Lastly, the *George Canning*, from Chaleur Bay, in the Gulf of St. Lawrence, and bound to Aberdeen, was lost at St. Shot's, during a dense fog, 17th of June, 1829; but, happily, the crew, fourteen in number, saved themselves in an open boat, and arrived at St. John's.

The cause of these lamentable events must unquestionably be the operation of a stream current, setting from the Gulf of St. Lawrence to the east and N.E. Major Rennell has shown, in the preceding work, (pages 56, 57,) how one current may be impeded and controlled by another, as well as by a shoal-bank or by land; and this appears to be the case in the present instance; for the S.W. current, from the Grand Bank, so opposes the *easterly* one as to limit its operation *eastward*, and to give it a *northern* inflection; thus producing the *indraughts* into the Bay of Placentia and other bays.

An experienced commander, long in the Newfoundland trade, has said that the branch of current which appears to come from Hudson's Bay, always sets to the south-westward (perhaps S.S.W.) off the eastern coast of Newfoundland: sometimes at the rate of two miles in the hour; its strength, however, varying with the direction and force of the wind. Passing down the eastern coast of Newfoundland, it turns about Cape Race, and sets thence, along the south side of the island, until it meets with the current from the St. Lawrence, a little to the westward of St. Pierre and Miquelon Islands.

When the Virgin Rocks, lying about 80 miles W. by S. from Cape Race, were surveyed in July, 1829, the current set over them to the W.S.W. at the rate of one mile an hour.

It is probable that this westerly current impinges on the easterly one, and continues its course, with diminishing velocity, towards

Breton Island, where it blends with that branch of the St. Lawrence stream which sets to the S.W. between Sable Island and Nova-Scotia, as shown in Chart II.

The sea between the Grand Bank of Newfoundland and the Banks of Nova-Scotia is distinguished by its drifts of *cold* water, varying with the wind and seasons.

To the south-westerly current, setting towards the eastern coast of Newfoundland, has been attributed the loss of the *Tweed*, frigate, bound to St. John's, which was wrecked upon the coast near Cape Spear, in the night of the 5th of November, 1813.—

EDITOR.

ARCTIC CURRENT.—The brig *Anne*, of Poole, William Dayment, master, sailed from Greenspond, Newfoundland, 19th of January, 1821, and in the evening encountered several floating islands of ice. On the following morning, at sun-rise, the ship was so completely enveloped in ice that there appeared no means of escape, even from the tops of the masts. The ice, in its whole extent, rose about 14 feet above the surface of the water; it drifted towards the south-east, and bore the ship along with it twenty-nine successive days. On the 17th of February, Captain D. being 300 miles east of Cape Race, in lat. 44° 37′ N. lat., perceived an opening to the South-east, and succeeded in disengaging himself. From the 29th of January to the 3d of February, the brig only made four miles a day; and during the 29 days this singular navigation lasted, he descried near 100 very extensive mountains of compact ice. See page 245.

We now conclude with giving the following note, which indicates the northerly drifts of the Head of the Atlantic during the winter season; for it has been seen that our knowledge of the currents in this region has been limited to the spring and summer. It goes, therefore, to corroborate the common opinion that, although in early summer the currents here are generally prevalent to the south and S.W., yet that they have a contrary direction in the other parts of the year.

Northerly Current towards Iceland.—A bottle from H.M.S. *Hecla*, Captain Parry, in lat. 56° 36′, long. 25° 45′ W., 13th of October, 1820, was found on the 6th or 7th of March, 1821, on

the coast of the district of Sónderamt, or south coast of Iceland: notice of which was transmitted to the Admiralty.

Another bottle, from the *Rising Sun*, S. H. Bennett, master, in latitude 50° 32′ N., long. 27° W., 31st of October, 1829, was found on the coast of Iceland, in April 1831: and another, from the *Urania*, of Leven, in latitude 56° N., and long. 16½ W., was found on the same coast, in the same month, 1831.—*Notice transmitted to Copenhagen.*

THE END.

ERRATA.

Page 40, the figure 2, prefixed to the section, to be 9.
105, line 12 from the bottom, *of sea* to read *of the sea.*
189, line 17, for Canavarel read Canaveral, as in p. 188.

GILBERT & RIVINGTON, PRINTERS,
St. John's Square, London.